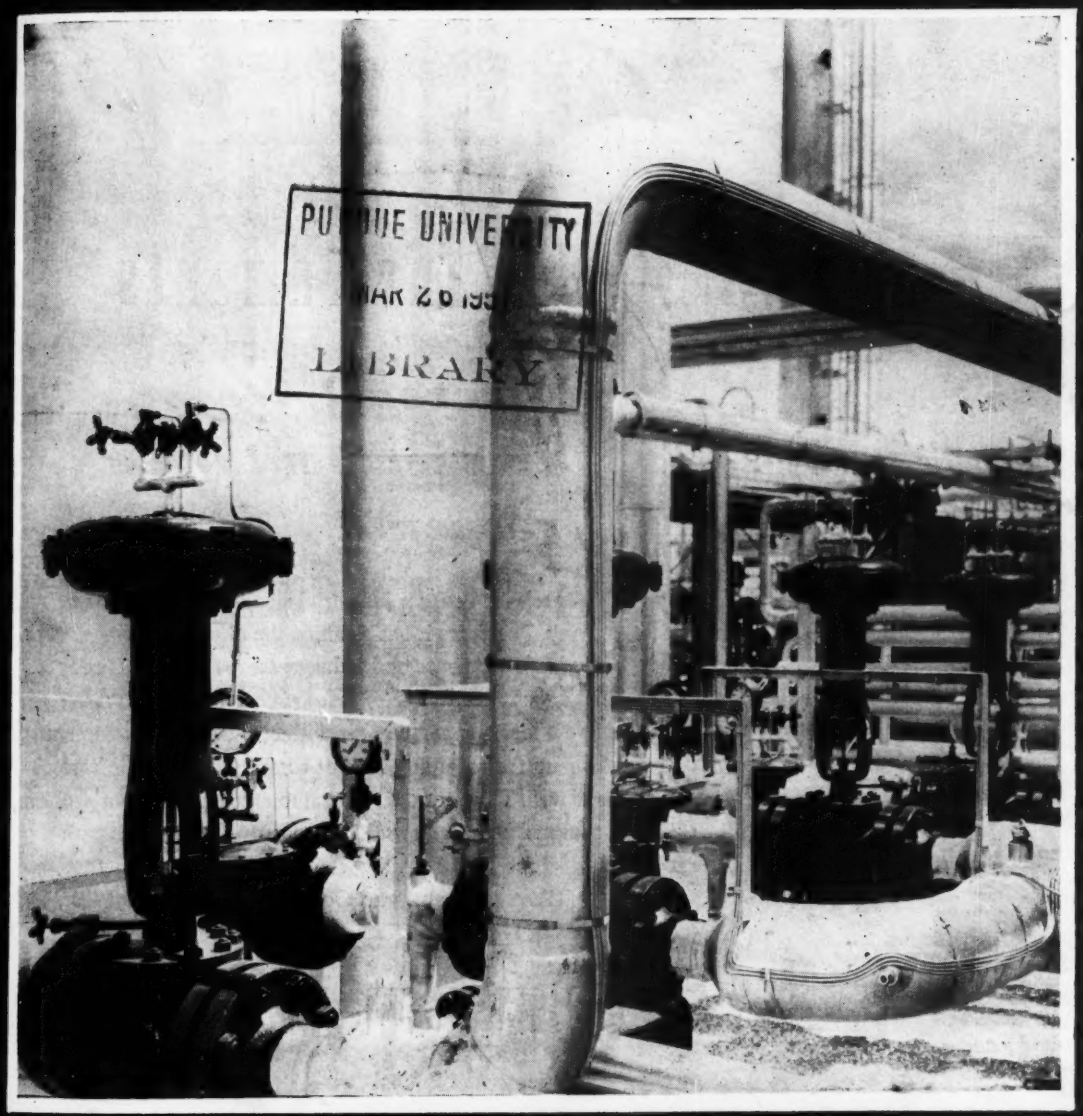
Instruments

THE MAGAZINE of MEASUREMENT and CONTROL

Vol. 24 MARCH 1951 No. 3

INCLUDING THE *Journal of the Instrument Society of America*

AND THE *Journal of the Southern California Meter Association*



Pneumatic system for Mason-Neilan control valves in Magnolia Petroleum's Chitwood, Okla. gasoline plant utilizes aluminum tubing. **See page 324.** *(Photo courtesy Aluminum Co. of America).*

At the Nerve Centers of Industry

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LIGHT Indicating, Recording, Controlling

PRESSURE Indicating, Recording, Controlling

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There's far broader industrial significance to the name WESTON today. For years it has signified the electrical *measurement standards* of science and industry the world over. Today it covers *the broadest line of industrial instrumentation* ever offered under one name . . . including measuring instruments, and instruments for recording and for controlling energy in various forms as well. Thus, for the solution to any measurement problem, or for complex process control, *all* industry can now turn with confidence to one source . . . the leader in precise instrumentation . . . WESTON Electrical Instrument Corporation, Newark 5, N. J., manufacturers of Weston and Tagliabue instruments.

WESTON WESTON TAG

Instruments

Typical set-up for measuring characteristics of r-f coil. Types 1330-A Bridge Oscillator, 821-A Twin T Impedance Measuring Circuit and a communications-type receiver. The oscillator is equally suited to use with other bridges such as the Type 716-C Capacitance Bridge and the Types 916-A and 916-AL R-F Bridges.

NEW GR Wide-Range BRIDGE OSCILLATOR

5 kc to 50 Mc—12 Volts Output

The new G-R Type 1330-A Bridge Oscillator is designed especially as a power source for bridge, antenna and general laboratory measurements. It is relatively inexpensive, has high output, excellent shielding and many operating conveniences. Among its features are:

- **WIDE FREQUENCY RANGE:** *5 kc to 50 Mc, carrier*
- **THREE MODULATION FREQUENCIES:** *internal a-m at line and at 400 c and 1,000 c, at two levels of approximately 30% and 60%*
- **GOOD OUTPUT:** *12 volts, open circuit; ¾ watt into 50-ohm load*
- **FREQUENCY ACCURACY:** *Carrier — ±2% above 150 kc, ±3% below, no load. Audio — ±5% for 400- and 1,000-cycles*
- **LOW LEAKAGE:** *about 50 μv per meter at 1 Mc, two feet from oscillator*
- **COAXIAL OUTPUT** *jacks, cable and adaptors permit complete shielding from oscillator to measuring instrument*
- **LOGARITHMIC DIAL:** *calibration logarithmic from 5 kc to 15 Mc*
- **INCREMENTAL-FREQUENCY DIAL:** *indicates increments of 0.1% per division from 5 kc to 15 Mc*
- **LOW DISTORTION:** *between 1% and 6% at 60% modulation level; r-f distortion 3% over most of range*
- **VERY COMPACT CONSTRUCTION:** *panel relay-rack width, only 7 inches high; cabinet 9 inches deep*
- **EASY SERVICING:** *oscillator plugs out of shielding box and has servicing cable to test instrument*

Type 1330-A Bridge Oscillator . . . $525.00

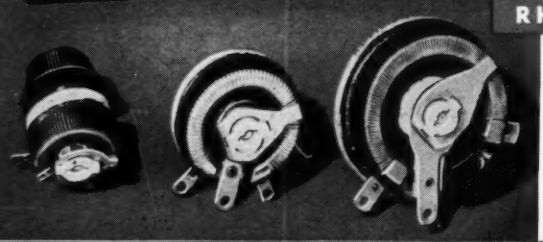
Excellent mechanical construction throughout. Oscillator assembly plugs into deep brass box; double cover completes shielding. Note servicing cable permitting instrument to be tested on bench.

GENERAL RADIO COMPANY Cambridge 39, Massachusetts

90 West St., New York 6 920 S. Michigan Ave., Chicago 5 1000 N. Seward St., Los Angeles 38

Mr. Manufacturer:

To get the best delivery on OHMITE resistance components, tailor your needs to these "standard" OHMITE items...



RHEOSTATS

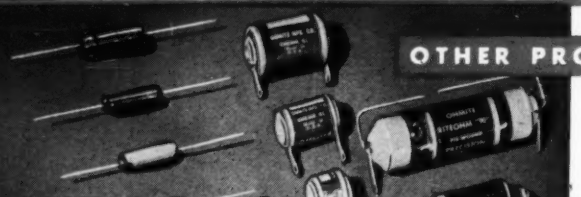
The Ohmite series of standard, close control rheostats is the most extensive available—so it is easy to select a size to fit your application. There are ten sizes, ranging from 25 to 1000 watts, with many standard resistance values in each size. All models have the Ohmite all-ceramic construction, with winding permanently locked in vitreous enamel, and smoothly gliding metal-graphite brush.

RESISTORS

The extensive range of Ohmite types and sizes makes possible an almost endless variety of standard resistors to meet your needs. The Ohmite line includes more than 60 core sizes, in a wide range of wattage and resistance values. There are also 18 types of resistor terminals available. Included in the standard Ohmite line are fixed, adjustable, tapped, non-inductive, and precision resistors. Specially developed vitreous enamel provides years of unfailing performance.

TAP SWITCHES

Ohmite tap switches are supplied in five standard models, rated at 10, 15, 25, 50, and 100 amperes, a.c. They combine high current capacity and a large number of taps with unusual compactness. Their sturdy, one-piece ceramic bodies provide permanent non-arcing insulation. Their heavy silver-to-silver contacts have a self-cleaning action and provide continuous, dependable contact with low resistance. Ohmite tap switches are supplied in enclosed or open, shorting or non-shorting types.



OTHER PRODUCTS

Ohmite offers an extensive line of standard precision, non-inductive resistors in ½- and 1-watt sizes, in the standard type, vitreous-enameled type, or hermetically sealed in glass. They have an accuracy of ±1%. Ohmite non-inductive vitreous-enameled resistors are also available in standard 50-, 100-, and 160-watt sizes in a wide range of resistance values. In addition, Ohmite provides radio-frequency plate chokes, power line chokes, and dummy antennas.

Write ON COMPANY LETTERHEAD FOR CATALOG AND ENGINEERING MANUAL NO. 40

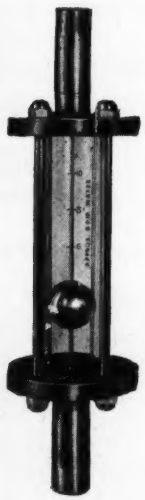
Be Right with OHMITE®

RHEOSTATS • RESISTORS • TAP SWITCHES

OHMITE MFG. CO.,
4857 Flournoy St.,
Chicago 44, Ill.

Low-Cost Flow Indicators Assist In Close Process Control

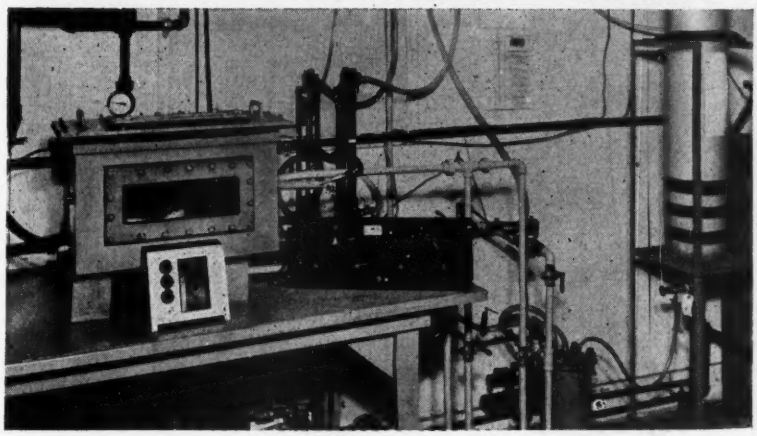
Ball Flow Indicators, a stock item, are typical of the many types of flow indicators designed by SK to permit visual inspection of flow in a pipe line. Very reasonable in cost, their use provides the necessary positive knowledge of flow conditions to insure proper control, thus conserving power, saving costly batches, insuring continuous process operation and preventing damage to expensive equipment.



The SK Ball Flow Indicator illustrated provides both a visual indication of flow and the approximate rate of flow. A moving brass ball acts as the indicator, and neoprene gaskets are used to seal the glass tube—permitting this type indicator to be used with lubricating oils and many solvents.

You, too, might profit, as many have, by using flow indicators in your operations. *Send for details.*

SK ROTAMETERS CONTROL FLOW IN NEW GAS PLATING PROCESS



A new gas plating process under development at Commonwealth Engineering Company of Ohio utilizes the volatility and decomposition characteristics of certain metallic compounds such as carbonyls, nitrosyls, hydrides, salts, and metal organics to plate both metallic and non-metallic materials. Results of this process are similar in many respects to those obtained by electroplating, however, gas plating permits the plating of non-conductors of electricity such as paper, plastics, tile and other non-metallic materials.

In this new process, SK Rotameters play an important role. In the pilot set-up shown above, one SK Fig. 1891 Universal Rotameter is used to control the flow of carrier gas, usually carbon dioxide, while another is used to control the flow of nickel carbonyl-carrier gas mixture as it comes from a carburetor. Since the ratio between the nickel carbonyl and the carrier gas determines, to a considerable degree, the character of the films deposited, the importance of providing such accurate flow measurement can be realized.

SK Universal Rotameters are available from stock. *For detailed information, write for Bulletin* 18-*RB.*

NEW USE FOR ROTAMETERS

New uses for SK Rotameters are constantly developing. One of the most unique and distinctive applications is the recent use of a Rotameter for measuring blood in connection with experiments on an artificial kidney and an artificial heart. The Rotameter acts as an accurate metering device and makes it possible to utilize whole blood without coagulation. It was surprisingly noted during experiments that the viscosity of the blood is not too appreciable and is variable depending on whether a man's or woman's blood was used.

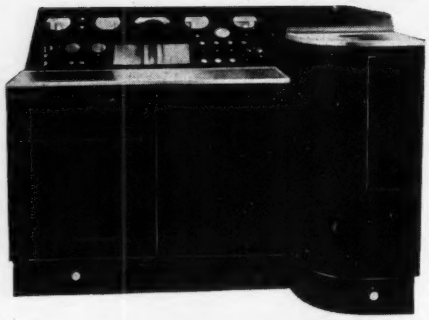
Possibly you can use a Rotameter application in your operation, too. *Ask for Bulletin* 18-*RA—it gives you a brief description and application of all standard SK Rotameters and briefly describes complete bulletins on all types.*

Manufacturing Engineers

-from design to installation of instruments

FALSTROM

SEE OUR CATALOG IN SWEET'S



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Instruments

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LEWIS

RESISTANCE THERMOMETER AND ACCESSORIES

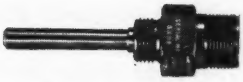
The Model 62 RT4F Resistance Thermometer is a sturdy, easy to read instrument with a six inch hand drawn scale. It is suitable for use in moving vehicles, is excellent for flight testing or for permanent panel installations. Operated by an ordinary dry cell and calibrated to standard "AN" bulb curves, this instrument is ideal for use with any of the resistance bulbs illustrated below. Other ranges available in °C or °F.

ACCESSORIES — RESISTANCE BULBS AND SWITCHES

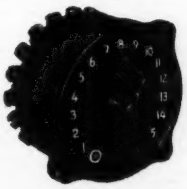
Lewis Selector Switches have been used for years in automotive test work as well as in permanent installations. Simple, sturdy construction plus finest materials combine to give long service.

FREE AIR

2" SIZE TO 4 POINTS

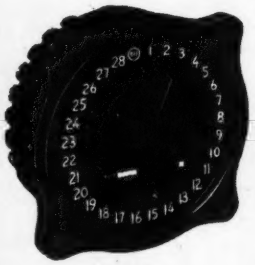


THREADED "AN" TYPE



3" SIZE TO 20 POINTS

THREADED "AN" TYPE



4" SIZE TO 28 POINTS

BAYONET TYPE FOR CYLINDER HEAD TEMPERATURE

Lewis Resistance Bulbs are adaptable for use with the 62RT4F Resistance Thermometer or with standard aircraft panel indicators. Special purpose bulbs with stem variations or for high temperature applications are available.

We invite inquiries on your temperature measuring problems.

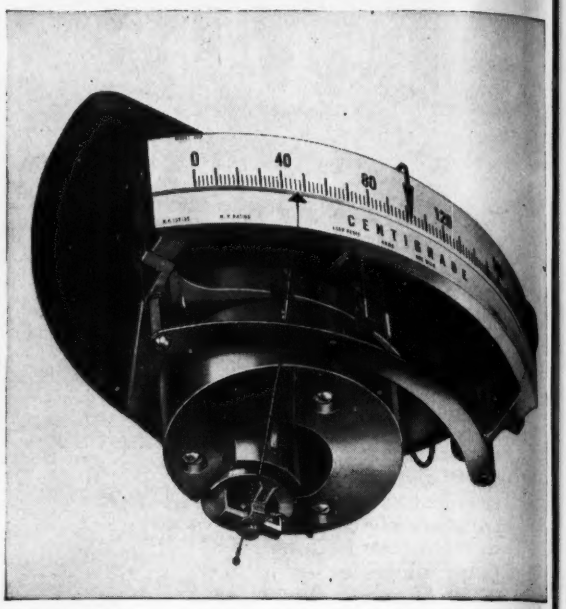
THE LEWIS ENGINEERING CO.

Specialists in Electrical Temperature Measurements

NAUGATUCK, CONNECTICUT

ACCURATE WITHIN 3/4 OF 1 PER CENT

G-E Type HP-3 pyrometer provides temperature indication and 2-position control of heating apparatus.



Heart of G-E pyrometers: This sturdy indicator assembly has heavy alnico magnet and lightweight armature.

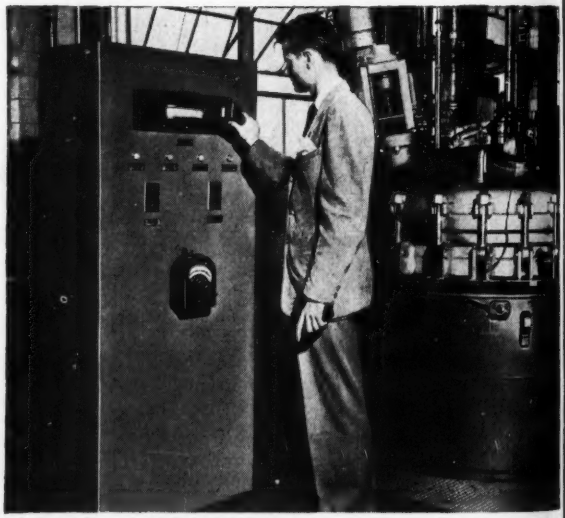
PYROMETER EQUIPMENT

The new G-E pyrometer has an exceptionally high accuracy—¾ of 1 per cent of full scale. But it also has the ability to hold this accuracy despite shock and vibration. The reason is the inherently sound construction. The instrument has a powerful, heavy (3¼ lb), alnico magnet and a featherweight (one gram) moving coil. This combination (high torque and low weight) results in accurate performance even under the most severe operating conditions.

Other features of this new G-E pyrometer equipment include: Built-in automatic cold-junction compensation that prevents changes in ambient temperature from appreciably affecting performance; gaskets at both base plate and zero-setting mechanism that keep out dirt, dust, and moisture; and an antiglare glass cover fitted over a seven-inch antiparallax scale that makes a G-E pyrometer easy to read.

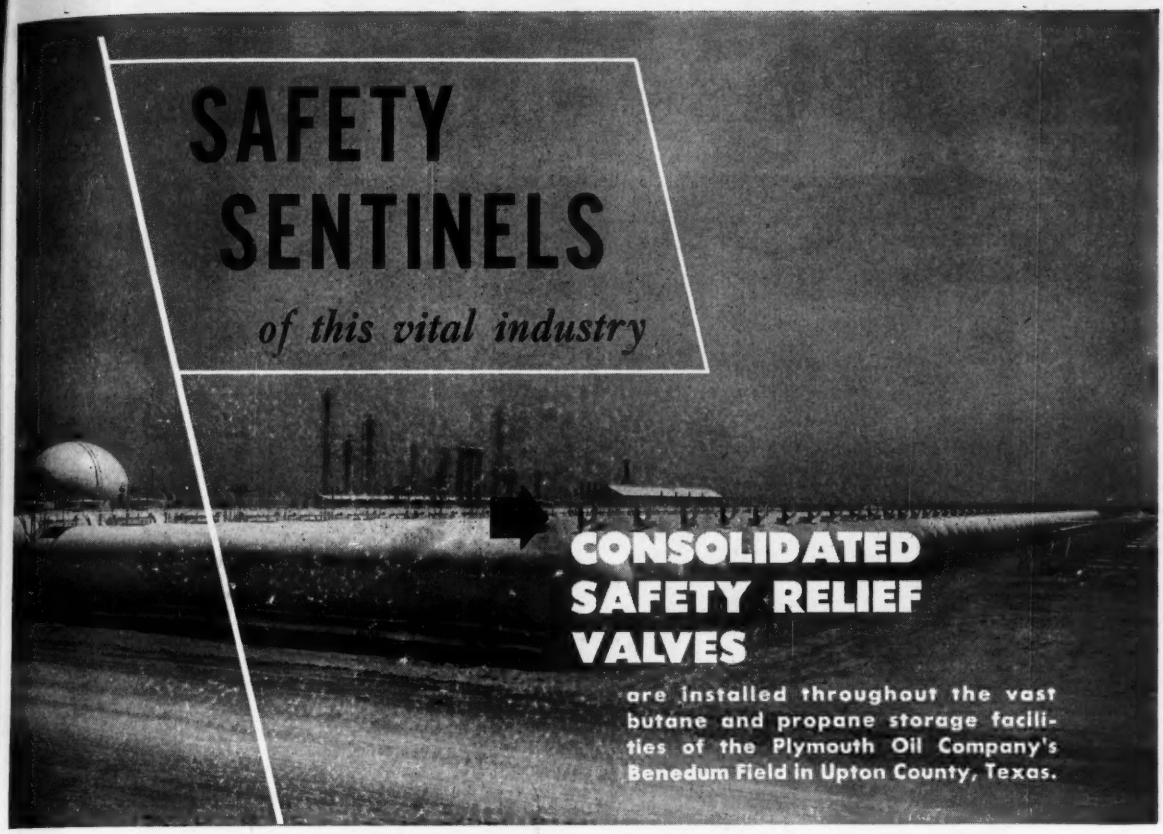
This new equipment is made in indicating, protecting, and two- and three-position control forms. It is available in a variety of standard temperature ranges in the 0-3000 F span. For complete details, write for Bulletin GEC-713. *General Electric Company, Schenectady, New York.*

Also available: a complete line of thermocouples.



Control unit of HP-3 pyrometer being inspected. The HP-3 is used here with a compound vacuum-treating tank.

GENERAL ELECTRIC


SAFETY
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are installed throughout the vast butane and propane storage facilities of the Plymouth Oil Company's Benedum Field in Upton County, Texas.

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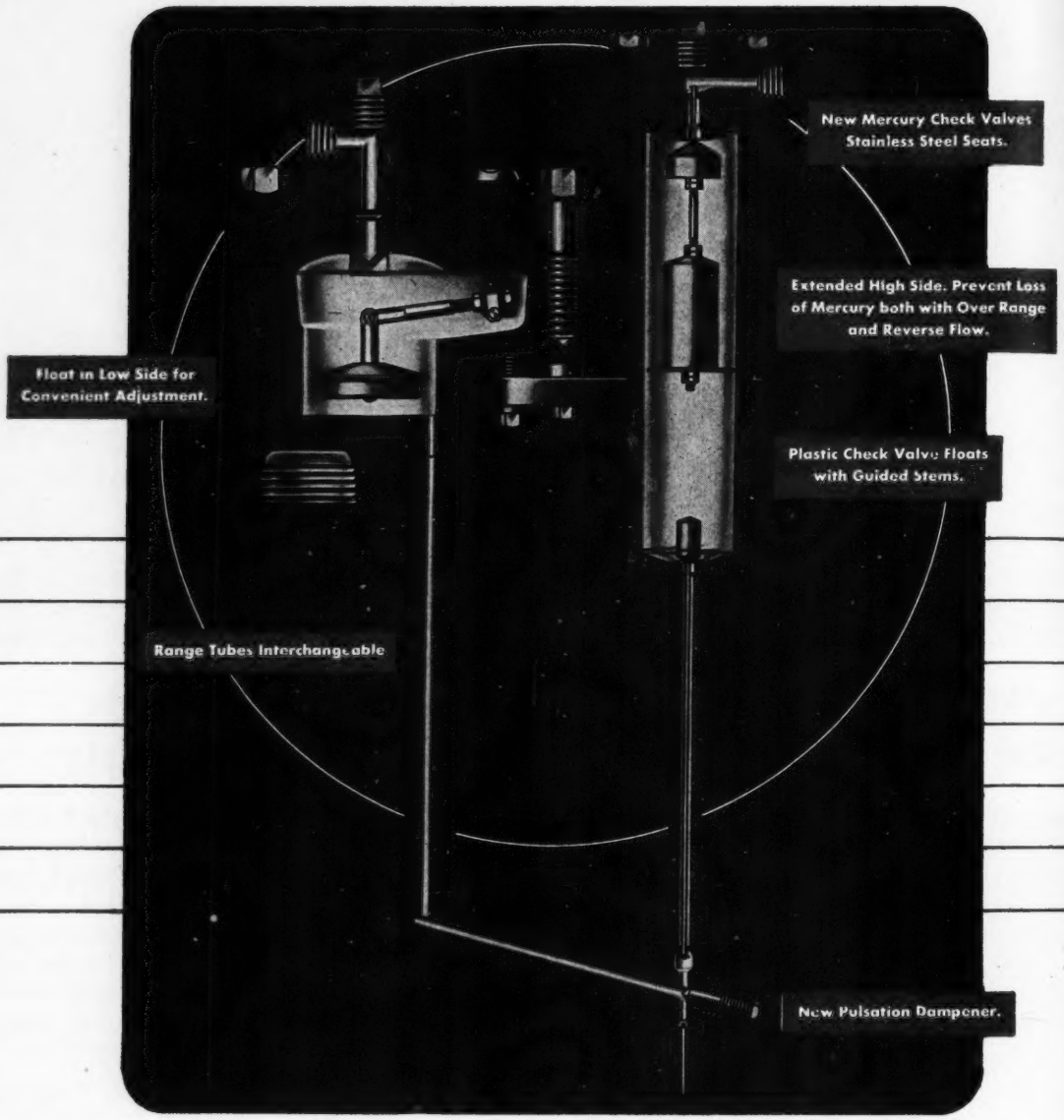
New Mercury Check Valves Stainless Steel Seats.
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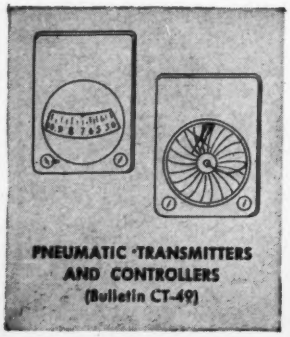
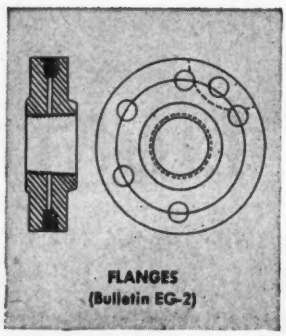
Plastic Check Valve Floats with Guided Stems.
Range Tubes Interchangeable
New Pulsation Dampener.



PNEUMATIC TRANSMITTERS AND CONTROLLERS
(Bulletin CT-49)

HIGH PRESSURE IRONCASE DISPLACEMENT METERS
(Bulletin 50-A)



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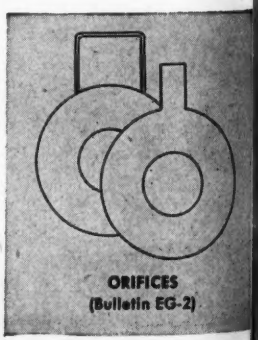


ORIFICES
(Bulletin EG-2)

ve and built for 5000# w.p.

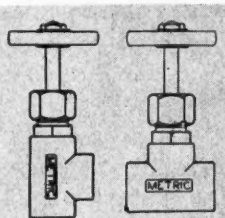
In response to insistent demands from gas and oil production men, the Model A-88 5000# American-Westcott Orifice Meter has been developed for high pressure services.

Designed in every way to operate safely and accurately under these pressures, the Model A-88 5000# Orifice Meter provides every feature that has made American-Westcott Orifice Meters outstanding for accuracy, simplicity and low maintenance cost. Its new design incorporates the proven features of the American-Westcott Orifice Meter and the many recent improvements in the A-88 Series to provide an accurate, rugged meter for today's higher operating pressures.

1. **Available in 50" and 100" ranges.**
2. **Low-side body constructed of forged steel of high tensile strength — high-side body made of extra heavy seamless steel.**
3. **Hydrostatically tested to 10,000 psi.**
4. **Adjustments easily made without disturbing working parts.**
5. **All parts can be handled and adjusted by small standard tools.**
6. **Every part accessible for cleaning without removing or loosening any connections that affect accuracy.**
7. **High sides interchangeable without affecting gage line connections.**

These and other American-Westcott features provide simple, accurate, dependable orifice meters that will handle the toughest kinds of measurement problems under the most rugged field conditions, with a minimum of servicing. They maintain to the highest degree the century old American Meter Company tradition of "sustained accuracy at lower cost." Write for descriptive matter.

PILOT LOADED, LARGE CAPACITY CBV REGULATOR (Bulletin 50)



NEEDLE VALVES, SCREWED AND UNION BONNET (Specification Sheet)

AMERICAN METER COMPANY

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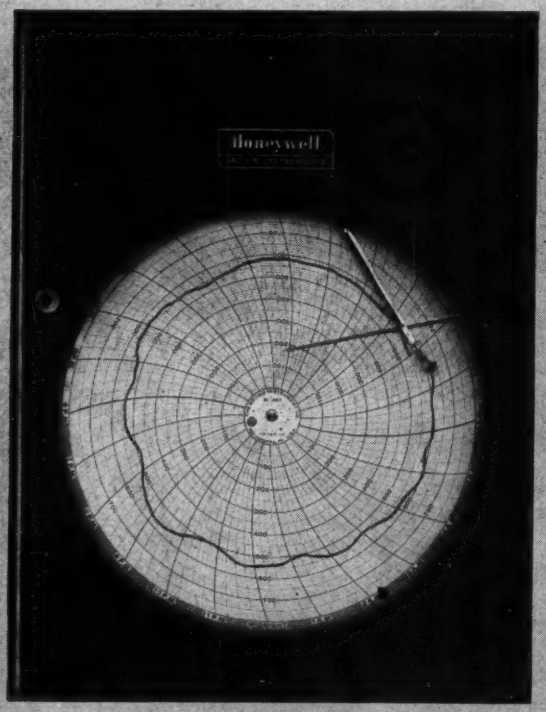


IT WILL PAY YOU TO TAKE A GOOD LOOK *at the* BROWN PRESSURE GAUGE

LIKE all other products that bear the Honeywell nameplate, the Brown Pressure Gauge has established a reputation for sound design and trouble-free performance, with flexibility . . . of practical importance to superintendents, engineers and instrument men.

The Brown Pressure Gauge is available with a variety of measuring elements, each designed for maximum performance in a particular pressure or vacuum range. The availability of the measuring elements in various materials, the ease of range change, the interchangeability of components, *plus* the easy accessibility of parts . . . all add up to a convenience that means simplified operation and maintenance for any application.

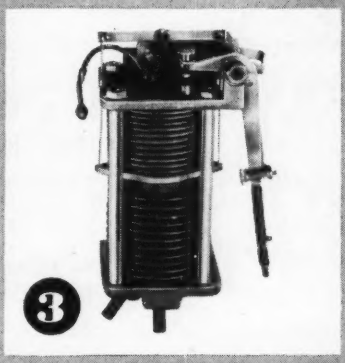
This instrument can be supplied with one, two or three pens . . . permitting combinations of pressure, temperature and flow measurement without sacrificing simplicity. And, the desired control form can be obtained from the electronic vane type which permit two or three-position electric control . . . or the pneumatic type control which permits on-off, proportional or proportional with automatic reset.

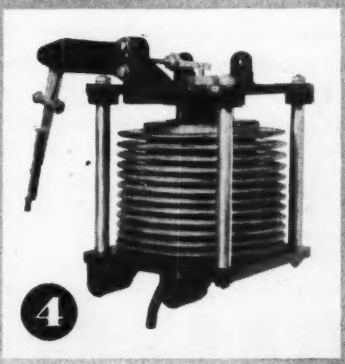
1 **SPIRAL...** Brown spiral pressure elements consist of a series of Bourdon tubes joined end to end and wound as a flat spiral. The movements of the tubes are additive, resulting in greater movement of the free end. These elements available in bronze, steel or stainless steel . . . are specially heat treated for accuracy and long life . . . possess ample torque and over-range capacity. For pressure ranges from 18 to 4000 psi.

2 **INTERMEDIATE SPRING AND BELLOWS...** This element is comprised of either a brass or stainless steel bellows, enclosed in a shell of corresponding material, and connected to the pressure source which moves it against the opposing force of a spring. A rod on the bottom of the bellows transmits this motion, through linkage, into pen movement. The unit possesses sufficient sensitivity for pressure ranges from 100 inches of water to 40 psi.

3 **ABSOLUTE PRESSURE UNIT...** This element, available in brass or stainless steel, consists of an evacuated bellows containing a calibrated spring and an actuating bellows connected internally with the measured pressure. Supporting castings connect the top of the evacuated bellows and the bottom of the actuating bellows. A movable plate between the two transmits their movement, through linkage, to the recording pen. Ranges from 0 to 60 inches of mercury absolute psi.

4 **LOW-RANGE SPRING AND BELLOWS...** This unit has a relatively large brass bellows, with internal pressure connection. Bellows movement is balanced by an externally mounted spring. For vacuum and compound ranges, a stainless steel spring is mounted in tandem and opposes the collapsing of the bellows caused by the partial vacuum. The element has ample power for pressure ranges from 5 to 90 inches of water.





Take a *good look* at all the features of the Brown Pressure Gauge . . . and then call in your local Honeywell engineer for a discussion of their utilization in your plant. Catalog sent on request.

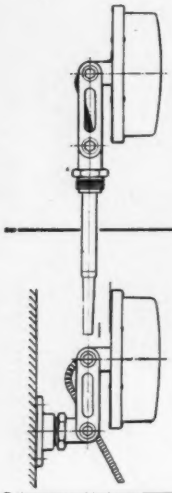
MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4482 Wayne Ave., Philadelphia 44, Pa. Offices in more than 80 principal cities of the United States, Canada and throughout the world.

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS

PALMER

mercury actuated Dial Thermometers

now in three types to suit any requirements

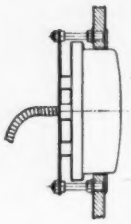


1 Rigid Stem Dial Thermometer

Rigid stem tapered bulb, interchangeable with standard industrial thermometer separable socket.

2 Wall Mounted Dial Thermometer

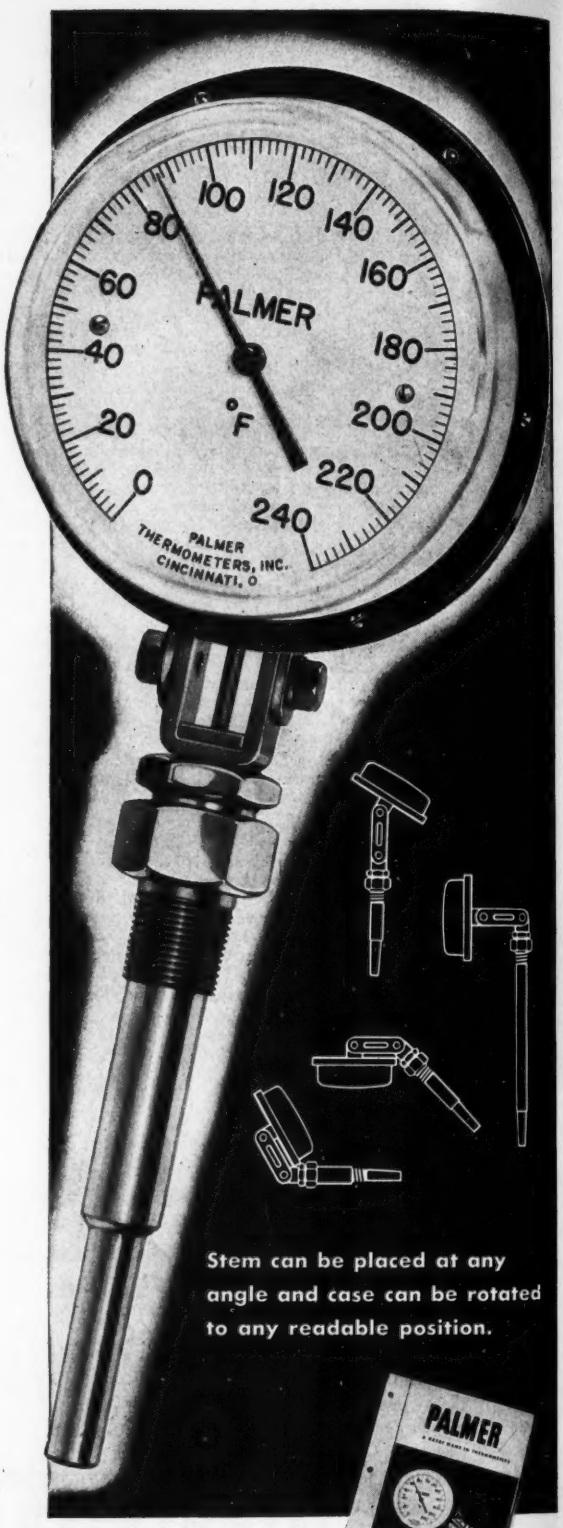
Wall mounted dial thermometer with flexible connecting armor. Case adjustable to easy reading position.



3 Flush Mounted Dial Thermometer

Flush mounted style for panel mounting with flexible connecting armor.

All three types have a full 4½" dial Face



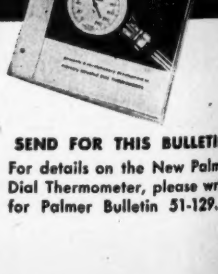
Stem can be placed at any angle and case can be rotated to any readable position.

for accuracy: Mercury actuated . . . Fully Compensated by Invar Compensation. Guaranteed Accurate 1 scale division.

for angularity: Can be adjusted to most readable position at any angle desired.

for readability: Bold Black Numbers . . . 11" of scale Reading Dial face can always be placed in easiest readable position.

for interchangeability: Always specify "PALMER" Separable sockets as they are interchangeable for Dial or Industrial type Thermometers.



SEND FOR THIS BULLETIN

For details on the New Palmer Dial Thermometer, please write for Palmer Bulletin 51-129.

PALMER

THERMOMETERS, INC.

Mfrs. of Industrial Laboratory, Recording and Dial Thermometers

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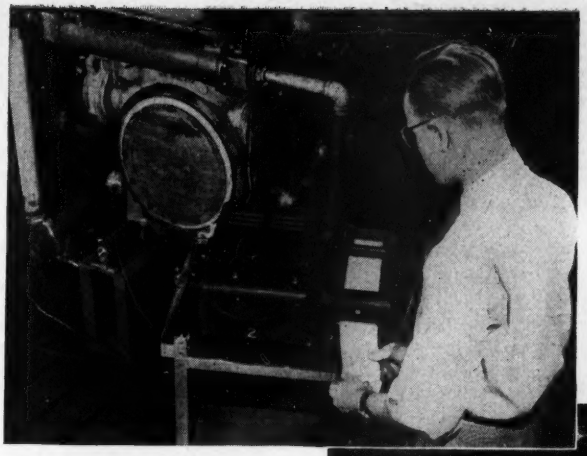


WHILE THE ENGINE RUNS, this Brush Strain Analyzer measures and records the engine torque instantaneously and accurately . . . eliminates much testing and plotting time. Full details in Bulletins 736 and 540.

WHILE THE ELECTRONS FLOW, this Brush D. C. Amplifier and Oscillograph measures and records the time constants of a reactor, eliminating hours formerly required for plotting. Write for Bulletins 460 and 540.

Instruments that multiply manpower

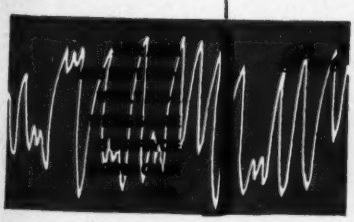
Are *you* taking advantage of the great time savings made possible by Brush recording analyzers?

Throughout industry, in research and production, Brush oscillographs provide immediately usable graphs of data which formerly took many man-hours to obtain and plot. In combination with other Brush instruments, these analyzers can be applied to a host of specialized problems . . . electrical, mechanical or acoustical.

Call your nearest Brush Representative to have him analyze your opportunities for manpower savings with Brush instruments.

THE *Brush* DEVELOPMENT COMPANY
DEPT. A-3, 3405 PERKINS AVENUE • CLEVELAND 14, OHIO, U. S. A.

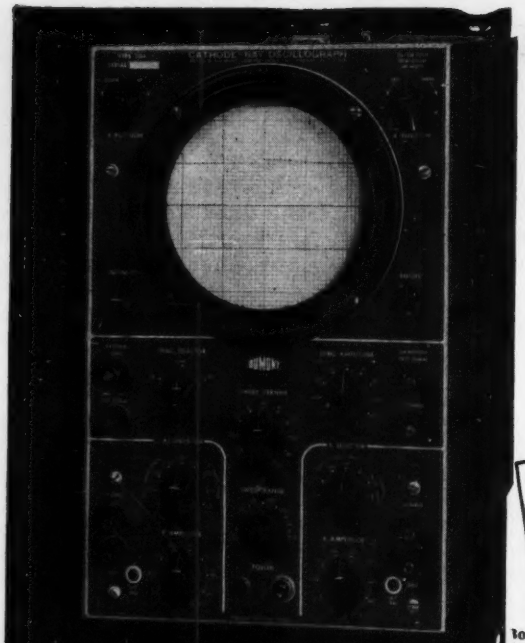
PIEZOELECTRIC CRYSTALS AND CERAMICS • MAGNETIC RECORDING
ELECTROACOUSTICS • ULTRASONICS • INDUSTRIAL & RESEARCH INSTRUMENTS



it in writing with a

BRUSH RECORDING ANALYZER

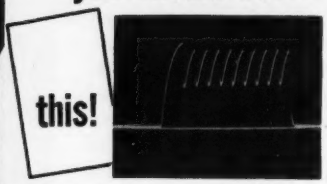
STRAIN ANALYZERS • SURFACE ANALYZERS • CONTOUR ANALYZERS • UNIVERSAL ANALYZERS • UNIFORMITY ANALYZERS



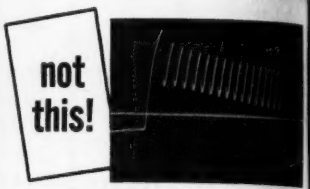
establish the signal's D-C LEVEL

...and measure its a-c and d-c components directly from the oscillograph

you should see...



Both a-c and d-c components are displayed through the d-c amplifiers of the Type 304-H. Base line represents zero volts.



The same signal, applied through a-c amplifiers exhibits a shifted reference line and tilt of the signal which make the oscillogram difficult to interpret.

DUMONT type 304-H

...to make direct measurements

THE TYPE 264-B VOLTAGE CALIBRATOR

Simply by applying its square-wave output to the oscillograph and producing a deflection equal to that of the signal, the amplitude of the signal may be read, in volts, directly from the calibrated dial of the Type 264-B. Or the Type 264-B will calibrate your oscillograph to read directly in volts per inch!

...to obtain permanent records

THE TYPE 296 OSCILLOGRAPH-RECORD CAMERA

To complete the study of the signal, permanent records, such as those above, are obtained most efficiently with this inexpensive, single-frame, 35-mm. camera. Operation of the camera is simple and foolproof; construction is compact and rugged. A high-quality f/2.8 coated lens is used, and focus is fixed for best oscillographic results.

The "Standard of Performance" for general-purpose cathode-ray oscillographs.

To study signals containing both a-c and d-c components, direct-coupled amplifiers such as those of the Type 304-H must be used. D-C amplifiers will maintain the true d-c level of the signal and display the actual relationship between the d-c and a-c components of the signal. Then by calibration of the Type 304-H with the Du Mont Type 264-B Voltage Calibrator, these components may be measured directly from the screen of the instrument.

Features such as driven sweeps, sweep expansion, extremely slow sweep speeds, and stabilized synchronization have made the Type 304-H the outstanding general-purpose cathode-ray oscillograph. Its sensitivity of 10 rms millivolts per inch and its versatility often eliminate the need for a second instrument to perform functions not within the range of the ordinary general-purpose oscillograph.

Portability contributes highly to the usefulness of the Type 304-H, especially in field work requiring good performance and in the laboratory where it serves many benches. The Type 304-H measures 13½" high, 8⅝" wide, 19" deep, and weighs only 50 pounds.

Write today for catalog...

Instrument Division, Allen B. Du Mont Labs., Inc.
1000 Main Avenue, Clifton, N.J., U.S.A.

DUMONT 20th YEAR AS PIONEER **in Oscillography**

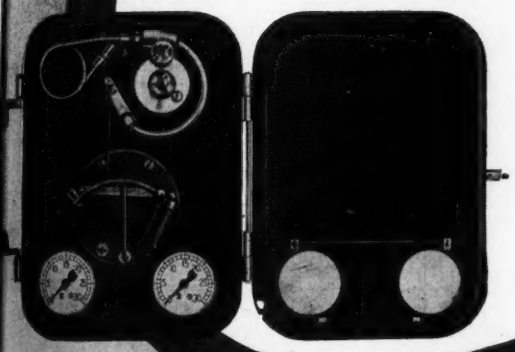
SENSITIVITY

VACUUM RELIEF
VACUUM
BACK PRESSURE
BOILER STEAM
REDUCED PRESSU
FLUID PRESS
PUMP DISC E
MAX - MU M

Type 1400 handles both positive and negative pressures, from high vacuum to 10,000 psi. It is adaptable to services requiring high sensitivity or to wide throttling ranges for dampening sensitivity. Overcomes hunting action which makes lined out pressure control difficult. Adjustable in the field for snap action. Bourdon-tube actuated.

BS&B Climax

TYPE 1400 PRESSURE CONTROLLERS



Here is how it works, explained step-by-step in this diagram. Simple, easy to maintain and ACCURATE!

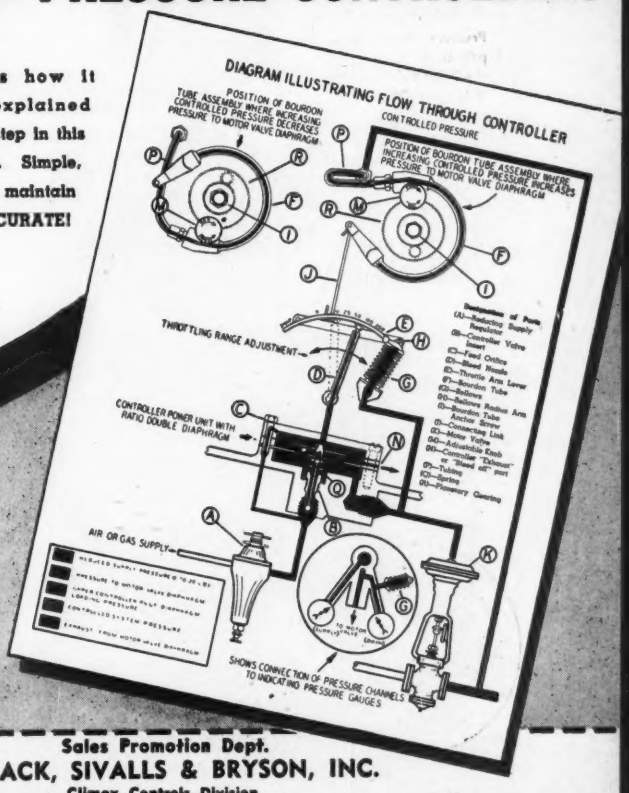


DIAGRAM ILLUSTRATING FLOW THROUGH CONTROLLER
POSITION OF BOURDON TUBE ASSEMBLY WHERE INCREASING CONTROLLED PRESSURE DECREASES PRESSURE TO MOTOR VALVE DIAPHRAGM
CONTROLLED PRESSURE
POSITION OF BOURDON TUBE ASSEMBLY WHERE INCREASING CONTROLLED PRESSURE INCREASES PRESSURE TO MOTOR VALVE DIAPHRAGM
THROTTLING RANGE ADJUSTMENT
CONTROLLER POWER UNIT WITH RATIO DOUBLE DIAPHRAGM
AIR OR GAS SUPPLY
SHOWS CONNECTION OF PRESSURE CHANNELS TO INDICATING PRESSURE GAUGES

Now you can be assured positive and sensitive response to pressure changes, with a controller characteristic usually obtained only in more expensive type recording instruments. Climax builds it right, for long service under all conditions. A multitude of special adaptations are possible... Ask your BS&B-Climax Man today!

You Can Count on Your Climax Man

His sound backlog of experience in process controls is available for your own use. He will be pleased to help you beat a tough problem. He is readily available, just check the coupon. Naturally, all inquiries are held in strictest confidence.

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I would like the complete story of the BS&B-Climax Type 1400 Pressure Controller . . . catalog, data, diagrams, prices. ☐ I want a Sales Engineer to call.

NAME_____

TITLE_____

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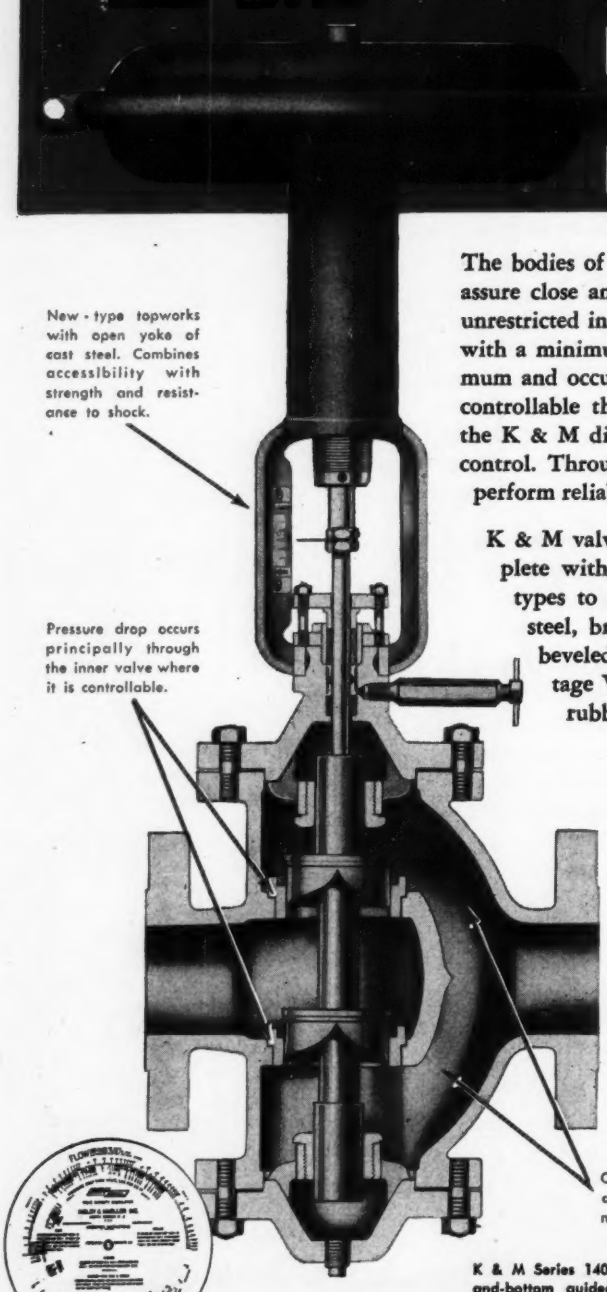
The Control Valves DESIGNED ESPECIALLY FOR INSTRUMENTATION



New-type topworks with open yoke of cast steel. Combines accessibility with strength and resistance to shock.

Pressure drop occurs principally through the inner valve where it is controllable.

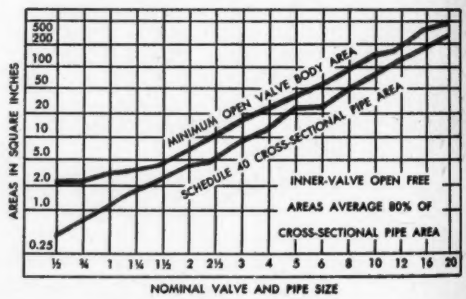
Over-size, streamlined body areas reduce turbulence and friction to a minimum and assure smooth, maximum flow.

K & M Series 1400 top-and-bottom guided diaphragm motor valve.

The bodies of K & M Control Valves are especially designed to assure close and positive control by instrumentation. They have unrestricted inlet and discharge passages and permit smooth flow with a minimum of turbulence. Pressure drop is held to a minimum and occurs principally through the inner valve where it is controllable through the full valve travel. The construction of the K & M diaphragm motors assures extreme precision in this control. Throughout, K & M Control Valves are engineered to perform reliably in *the most exacting applications.*

K & M valves are available in sizes from ½ to 20-inch, complete with diaphragm motor and are made in 13 different types to meet varying requirements. Constructed of semi-steel, bronze, cast steel or special alloys. Inner valves in beveled quick opening, percentage parabolic or percentage V-port design as standard. Facings range from soft rubber to stellite.

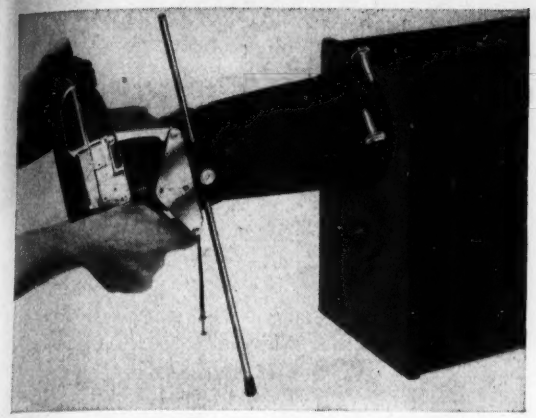
Because of their modern design, all K & M valve bodies have extremely high capacities in relation to corresponding pipe size:



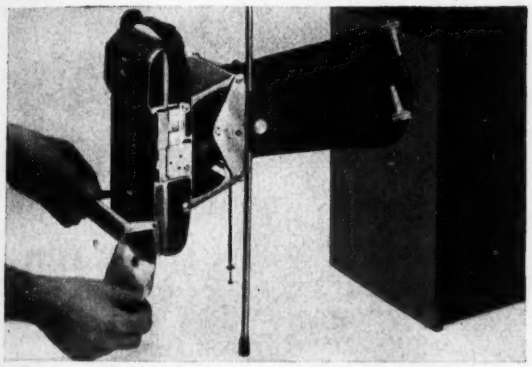
KIELEY & MUELLER

Established 1879

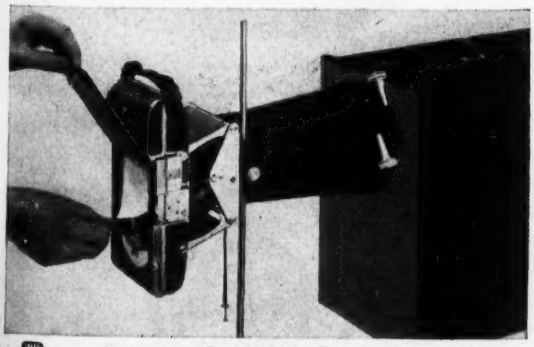
How to make Oscillograms FAST!



Set up the camera. The Fairchild-Polaroid camera consists of three units: adapter ring, hood, and camera body. To set it up, you place the handy adapter ring over the oscilloscope bezel, slip the hood into the ring, then snap the camera into the bayonet lock on the hood. That supporting rod is a safety feature that protects both camera and oscilloscope.



Pull the tab to finish exposed print. After a snap of the shutter, the exposure is made and you're ready to finish the print. If you want two exposures, it's easy to move the camera body down and make a second exposure. To finish the print, you merely pull tab at back of camera.



Remove the finished print. A minute after you've pulled the tab, the finished print is ready for evaluation. Just open the camera back and there it is. An easy job, but you have a photographically accurate record of the trace in less time than you could sketch it from memory.

—SET UP THE CAMERA
—SNAP THE SHUTTER
—SEE THE PRINT

ALL IN 3 MINUTES—or even less with the Fairchild-Polaroid® Oscilloscope Camera

The easiest way is the fastest way when you're photographing oscilloscope images with the Fairchild-Polaroid® Oscilloscope Camera.

No more darkroom processing! With this new camera it takes only two minutes (less if you're fast) to set up and snap the picture, one minute to finish a print. Each 3¼ x 4¼ print records traces exactly one-half life size to make comparisons easy.

Write for complete data and prices on F-284 Oscilloscope Camera Kit including camera, carrying case, and film. *Fairchild Camera and Instrument Corporation, 88-06 Van Wyck Boulevard, Jamaica 1, N. Y. Dept. 120-14F.*

SPECIFICATIONS

LENS—Special 75 mm. f/2.8 Wollensak Oscillo-anastigmat.

SHUTTER—Wollensak Alphax; speeds 1/25 sec. to 1/100 sec., "time," and "bulb."

FOCUS—Fixed (approx. 8 in.)

PICTURE SIZE—3¼ x 4¼ in. (2 or more images per print; 16 exposures per roll of film.)

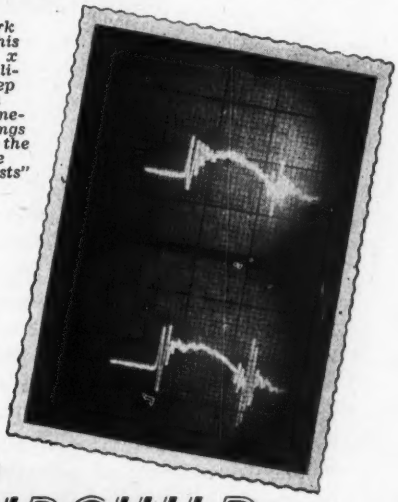
IMAGE SIZE—One-half reduction of scope image.

WRITING SPEED—to 1 in/μsec at only 3000V accelerating potential; higher speeds at higher voltages.

DIMENSIONS—Camera, 10½ x 5¼ x 6¼ in.; hood, 11 in. length, 7½ in. dia.; adapter, 2 in. width, 6⅝ in. max. dia.

WEIGHT—Complete, 7¾ lb.

Typical of the work being done with this camera is this 3¼ x 4¼ print of 35-millisecond single-sweep transient—one of a series of accelerometer-output recordings that made possible the completion of nine recorded "drop-tests" in 40 minutes.



FAIRCHILD
OSCILLOSCOPE RECORDING CAMERAS

See the Fairchild-Polaroid Oscilloscope Camera and the Fairchild Oscillo-Record Camera at the Radio Engineering Show, Booth 238-239.

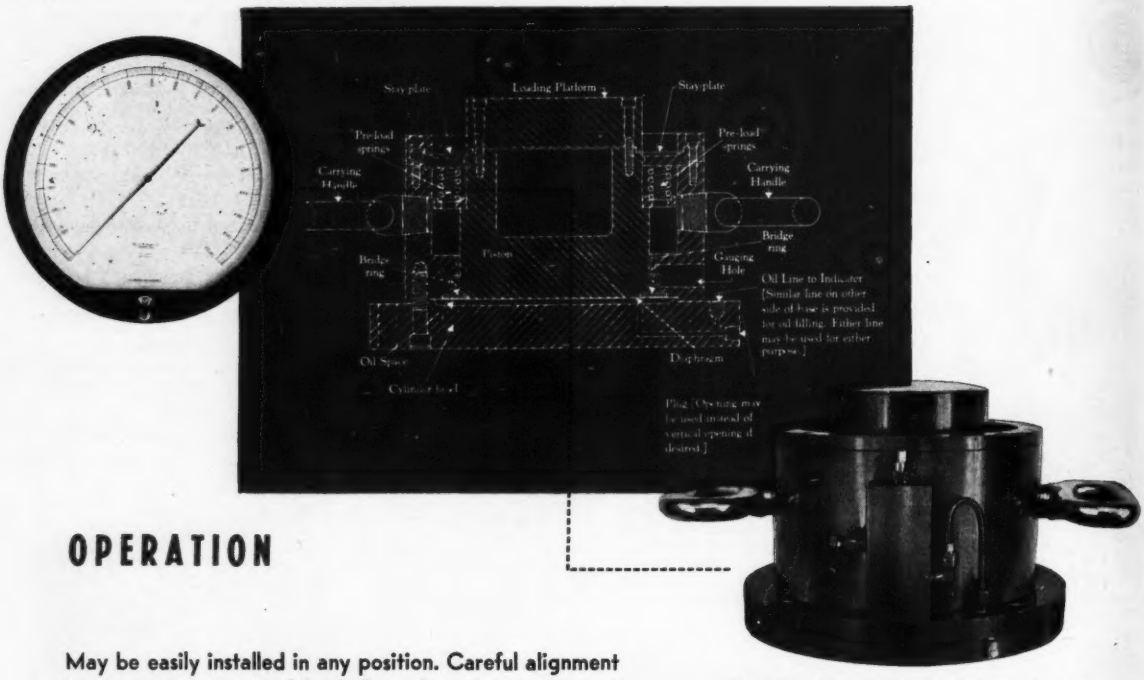
EMERY FORCE MEASURING SYSTEM FOR THE MEASUREMENT OF THRUST, TORQUE TENSION, COMPRESSION DYNAMOMETER FORCES AND OTHER SPECIAL FORCE PROBLEMS

SELF-CONTAINED: Compact and simple in construction; easy to install and use; no precise alignment required. A complete package—no additional equipment or external sources of power or air needed.

WIDE RANGE: Standard units for capacities to 100,000 lb.

ACCURACY: Within 1/10 of 1% of range; dial calibrated in desired units of force; no conversion factors or compensation needed.

NATURAL STABILITY: Less than .005" deflection under full load. High natural frequency. Withstands heavy vibratory or shock loading. No external dampeners or stabilizers required.



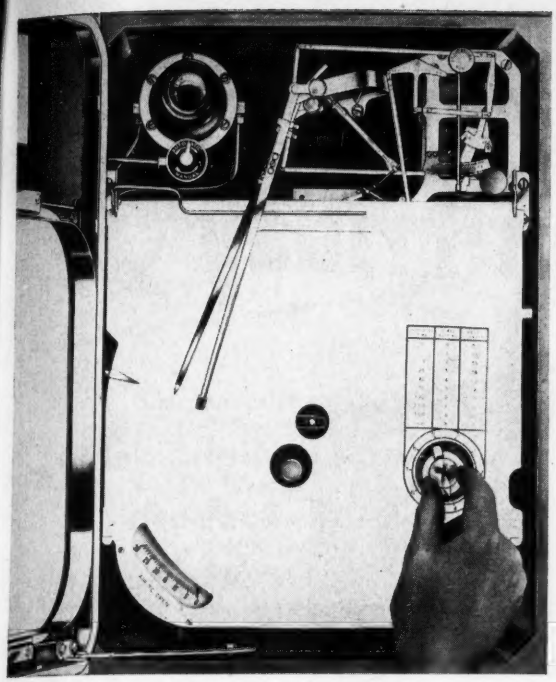
OPERATION

May be easily installed in any position. Careful alignment is unnecessary; no need for bell cranks or levers. Rugged construction, requires no maintenance. Force exerted on loading platform is converted into proportional hydraulic pressure; this is transmitted to an Emery Bourdon, or Tate-Emery, Indicator calibrated in the desired force units. Frictionless. Sensitivity and stability of action give excellent duplication of test results. Fast response. Cell can accommodate substantial cross loading or non-central loading without measurable loss in accuracy or sensitivity. Various combinations of indicators, recorders, high-frequency pick-ups, totalizers, and other special devices can be in the original installation or easily added later.

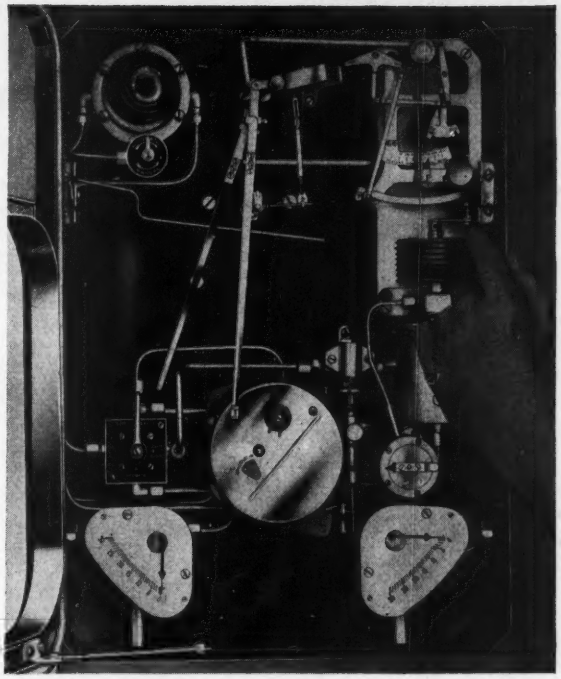
The basic Emery Hydraulic Cell, heart of the well-known Baldwin-Tate-Emery Testing Machines, used for years in important industrial, government and research laboratories. Over 2000 systems based on this cell are in use.

THE A.H.EMERY CO. 75 YEARS HYDRAULIC WEIGHING

THE A. H. EMERY CO. 687 MAIN STREET, STAMFORD, CONN.



EASIEST TO PUT INTO OPERATION—Calibrated control actions save hours of shutdown. Reset, derivative and proportional values can be exactly reproduced at any time on the same or any other Series 500 controller . . . merely by duplicating the setting. Thus: controller adjustments can be standardized for any process throughout a plant or national organization.



EASIEST TO SERVICE—Inherently simple design, using the fewest possible parts, plus extremely close-tolerance manufacturing . . . make the instrument thoroughly interchangeable, trouble-free and a cinch to service. For example: only one simple adjustment puts the system in exact calibration even after complete disassembly and reassembly.

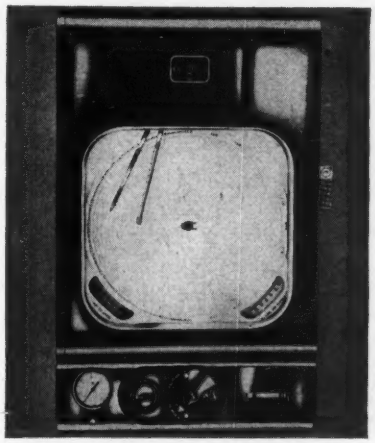
ONLY BRISTOL SERIES 500 CONTROLLERS GIVE YOU THIS EASE OF OPERATION

When you wish to reproduce a previous control action or duplicate one taking place at some other point, the Bristol Series 500 Air-Operated Controller permits you to do it merely by setting a dial.

Or, should the instrument require servicing, only one simple adjustment is needed to calibrate the control system and put it back in operation. Almost anyone can service this instrument.

Furthermore, users report that the Bristol Series 500 Controller requires practically no maintenance.

This outstanding instrument—a product of 60 years of experience—is completely described in Bulletin A120. THE BRISTOL COMPANY, 113 Bristol Road, Waterbury 20, Conn.



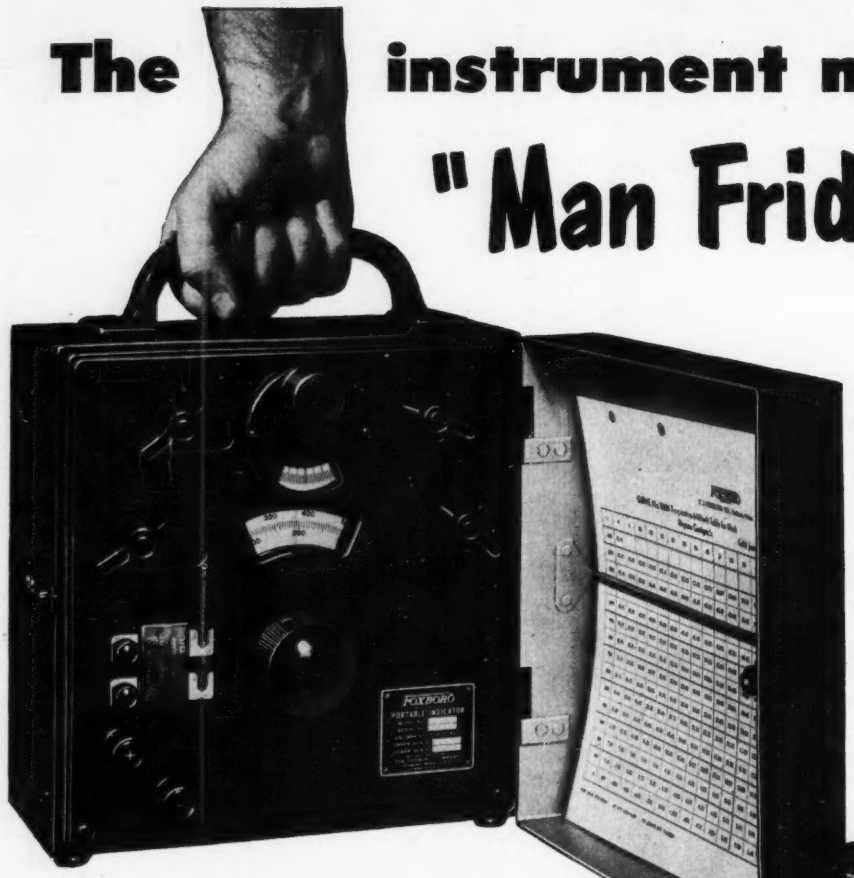
BRISTOL SERIES 500 CONTROLLERS are offered in five types—on-off, proportional, reset, derivative, reset plus derivative—to control temperature, flow, pressure, liquid level, humidity, pH. Conversion from one type to another can be made by the user. Model shown has exterpal-manual station with mechanical interlock for test and service.

THE DEPENDABLE GUIDEPOST OF INDUSTRY

BRISTOL

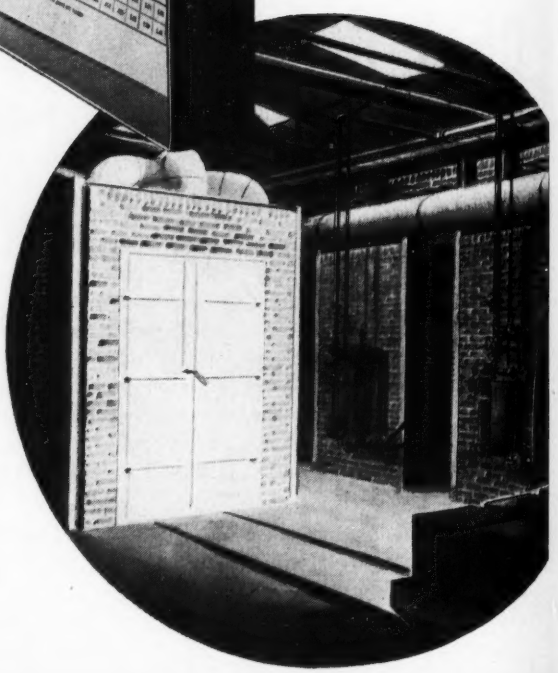
AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

The instrument man's "Man Friday"



High-fidelity Foxboro Portable Potentiometer

— metal cased and covered



You'll never run out of uses for this rugged, precision portable potentiometer. It's the most indispensable tool in the instrument man's kit! Use it to check overall accuracy of your temperature instruments and thermocouples; as a substitute temperature instrument during emergencies; for exploring temperatures not requiring continuous measurement.

The Foxboro Portable Potentiometer Indicator is accurate to ¼ of 1% of scale. Temperature dial has an extra long (17") scale for close, accurate reading, and *vernier dial* for precise balancing. Supplied with either single or double temperature scales to provide for different types of thermocouples . . . or for use with resistance bulbs. Weighs only 12½ lbs. Rugged metal case-and-cover protects the instrument from rough handling.

Write for detailed information on this outstanding Portable Potentiometer Indicator. **The Foxboro Co., 463 Neponset Ave., Foxboro, Mass., U. S. A.**

FOXBORO
REG. U. S. PAT. OFF.

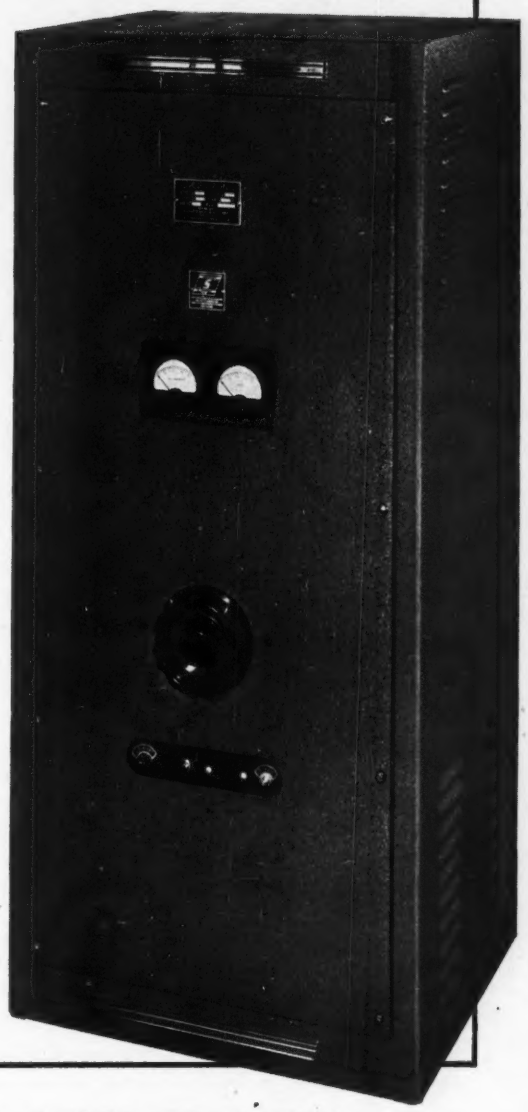
RECORDING · CONTROLLING · INDICATING INSTRUMENTS

specify Sorensen

RANGERS

(FULL-RANGE-VARIABLE DC SUPPLYS)

This versatile supply is a combination of the widely used Sorensen NOBATRON and a filter-variable output circuit.
The result gives a continuously variable output voltage regulated against line and load changes through the full range of the instrument.
Look at the specifications tabulated below — check them against your requirements. Where range of output, adaptability to diverse applications is essential, the Sorensen RANGER may well be your instrument of choice.



ELECTRICAL SPECIFICATIONS

Model No.	SR-10	SR-30	SR-50
Output range	0 - 135 VDC	0 - 30 VDC	0 - 13 VDC
Current range	1 - 10 amps	3 - 30 amps	5 - 50 amps
Input voltage	95 - 130 VAC, 50 - 60 cycles, single phase		
Regulation accuracy	± 0.25 percent at any voltage setting from 3 VDC to top rating		
Ripple	RMS max. 1% of output setting		

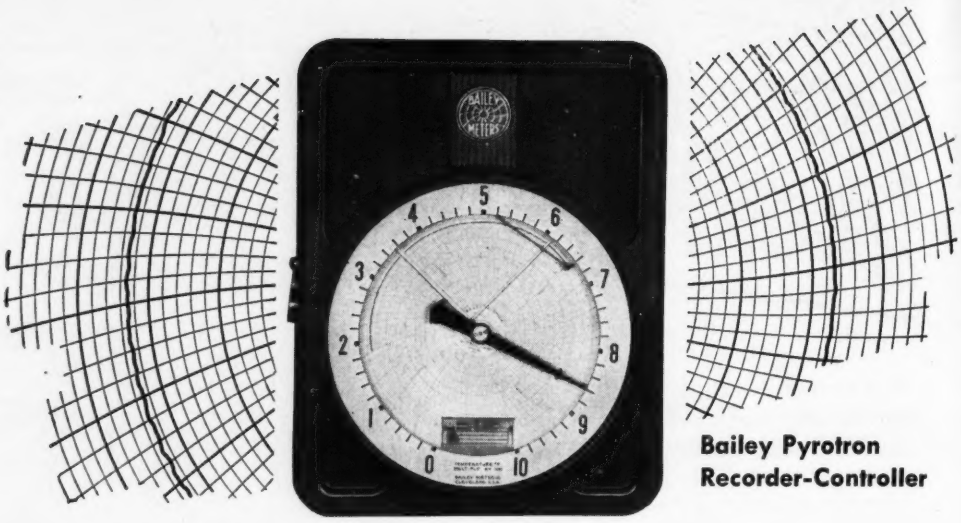
Meters — standard. Coarse and fine adjustment available.

Write for complete information.

For other regulated DC supplys, investigate Sorensen's line of NOBATRONS (low voltage) and B-NOBATRONS (high voltage).

POWER controlled converted

Sorensen and company, inc.
375 FAIRFIELD AVE. • STAMFORD, CONN.



Bailey Pyrotron Recorder-Controller

Looking for Better Temperature Instruments?

...Then check these features of Pyrotron Electronic Resistance Thermometers...

FUNDAMENTAL ACCURACY

Bailey Pyrotron Resistance Elements are made of highest purity platinum—the material used by the National Bureau of Standards in establishing basic standards for temperatures from −190°C to +660°C.

THREE TYPES OF CONTROL

Pyrotron Controllers may operate: on-off electrical systems by either electronic relays or electric contacts, modulated electronic systems, or air-operated systems. Two temperatures may be recorded on the same chart and controlled by a single instrument.

FACTS PUT INTO USABLE FORM

Bailey Pyrotrons may be arranged to put temperature facts into convenient usable forms. If two or more temperatures are related, they may be recorded as continuous records on the same chart for easy comparison. The average of several temperatures or the difference between two temperatures may be recorded as a single continuous record which may be retransmitted to a distant point or used to actuate a control system.

EASY INSTALLATION

Bailey Pyrotrons do not require careful leveling or protection against vibration. Three ordinary copper wires are all that is needed to connect each temperature sensitive element with the recorder. Power may be taken from any 115 volt 60 cycle circuit.

MINIMUM MAINTENANCE

The absence of galvanometers, batteries and standardizing equipment, together with the use of interchangeable unit assemblies, reduces Pyrotron maintenance to the vanishing point.

ABUNDANT POWER

A separate motor drive for each temperature furnishes abundant power to operate a recording pen, a controller and an alarm switch.

For the full story on this unusual electronic resistance thermometer which is suitable for ranges between −300°F and 1200°F, ask for Bulletin No. 230-C. P-21

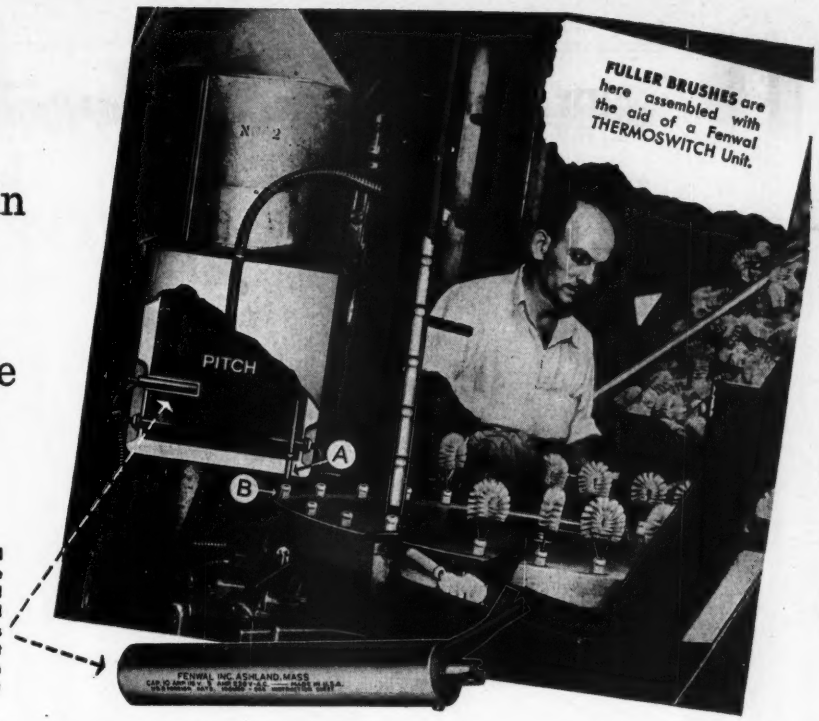
BAILEY METER COMPANY

1041 IVANHOE ROAD • • • CLEVELAND 10, OHIO

Controls for Processing

TEMPERATURE
PRESSURE
% OXYGEN
% COMBUSTION
FLOW
LEVEL
DENSITY
RATIO

Multi-Purpose Thermostat solves problem in Fuller Brush assembly—prevents damage to machinery, motor



FULLER BRUSHES are here assembled with the aid of a Fenwal THERMOSWITCH Unit.

INVERSE CARTRIDGE THERMOSWITCH UNIT #17001 which closes on temperature rise is inserted in well inside of pitch tank and connected in series to starting switch and magnetic contactors. Machinery operates only when pitch has reached the preset temperature that assures fluidity. It then moves through automatically operated spout (a) into hollow brush handle (b).

When vegetable brushes are assembled at the Fuller Brush plant, a pitch-like sealing compound is poured into the hollow handle of the brush. The brush is then inserted in the handle and completed brush moved on to packing room.

Trouble-point in this procedure was the sealing compound. If it were not heated to a fluid state before machinery was started, automatic spout was broken and motor burned out.

A low-cost Fenwal THERMOSWITCH Unit averted this stoppage by continually, *accurately* controlling the operation of the motor. Electric motor cannot now start until the compound has reached the desired temperature. Thus damage to machinery as well as motor is prevented.

Easy-to-install, easy-to-maintain Fenwal THERMOSWITCH thermostats solve all types of control problems in industry. Their activating control element is the single-metal shell that expands or contracts *instantaneously* with temperature changes, making or breaking the totally enclosed electrical contacts. It is this unique principle that enables THERMOSWITCH Units to effectively control *many* variables where heat is a factor.

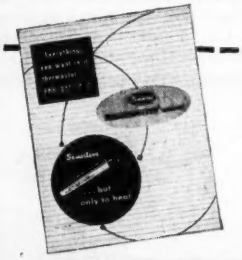
Mail the coupon today and find out how Fenwal THERMOSWITCH Controls can help you in your own processing.

Fenwal

THERMOSWITCH®

The Precision, Multi-Purpose, Thermostat Control

SENSITIVE...*but only to heat*



FREE!

Get this bulletin . . . see what Fenwal THERMOSWITCH Units can do for *you. Just fill in coupon and mail ...no obligation.*

FENWAL, INCORPORATED, 173 Pleasant St., Ashland, Mass.
111 South Burlington Ave., Los Angeles 4, Cal.

TEMPERATURE CONTROL ENGINEERS

Name.....Position.....

Company.....

Street.....

City.....Zone....State.....

I am chiefly interested in the applications checked:

- ☐ Heating
- ☐ Cooling
- ☐ Alarm (over-temperature, under-temperature)
- ☐ Timing (thermal)
- ☐ Humidity Control or Detection
- ☐ Vapor Level Control
- ☐ Pressure Control (by controlling vapor temperature)
- ☐ Radiant Heat Control

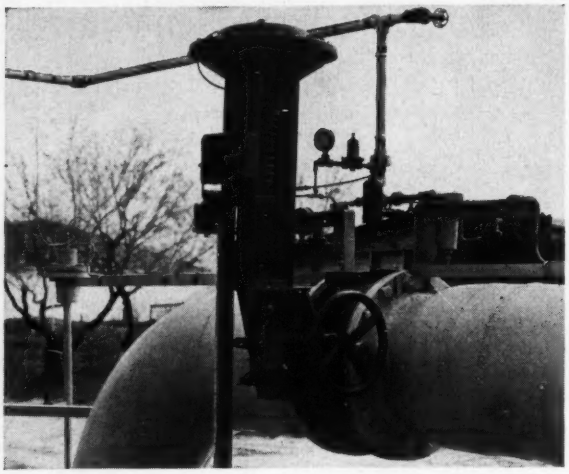
OTHER (Please fill in your special requirements)

.....

.....

R-S valvEvents

• EXCERPTS FROM THE R-S BOOK OF EXPERIENCE •



Minimum Pressure Drop

SAVES POWER

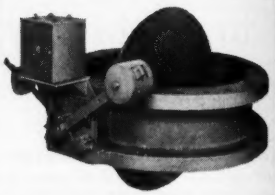
The beveled vane of an R-S Valve seats firmly against the valve body to produce commercially tight shut-off with metal-to-metal seat. A rubber seat produces drip-tight closure. In the open position the streamlined vane creates a Venturi action. Pressure drop in R-S Valves is low, and they therefore produce substantial savings in pumping costs.

Illustration shows a heavy duty R-S Valve used in the water system to a compressor house. Valve is equipped with diaphragm motor, handwheel control with self-locking worm and gear and declutching mechanism together with outboard bearing for operating shaft with goose neck support.

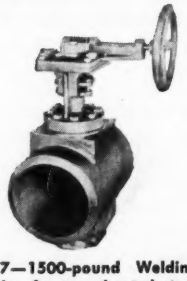
Every R-S Valve is engineered and constructed for rugged service and provided with such safety factors that it will give complete satisfaction in the service for which it is designed. Consult with your local R-S Valve Engineers or write direct.

R-S PRODUCTS CORPORATION
An S. Morgan Smith Company Subsidiary
4600 Germantown Avenue
Philadelphia 44, Pa.

No. 579—6-inch 15-pound Direct Action Float Valve with counter-weight assembly.



No. 628—Solenoid Trip Valve is used for emergency service. The solenoid can be arranged with the counter-weight mechanism to open or close the valve and hold it there in one position or the other. If for any reason the solenoid functions, the latch is tripped, which permits the counter-weight to open or close the valve by gravity. The assembly is suited to shut off the flow or to open a vent and requires manual reset. Can be constructed of any metal or alloy and in various sizes for air, gases, steam, oil, hydraulic and other services.

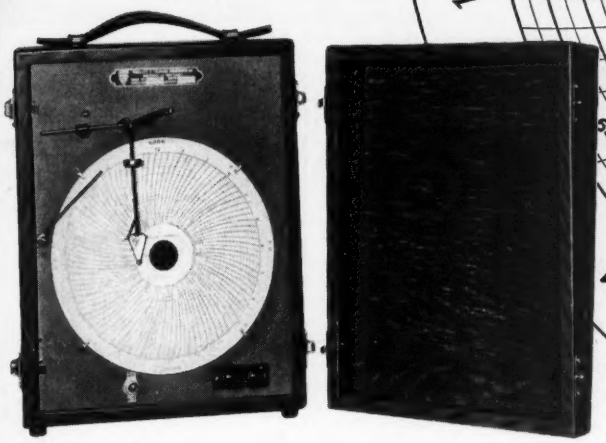


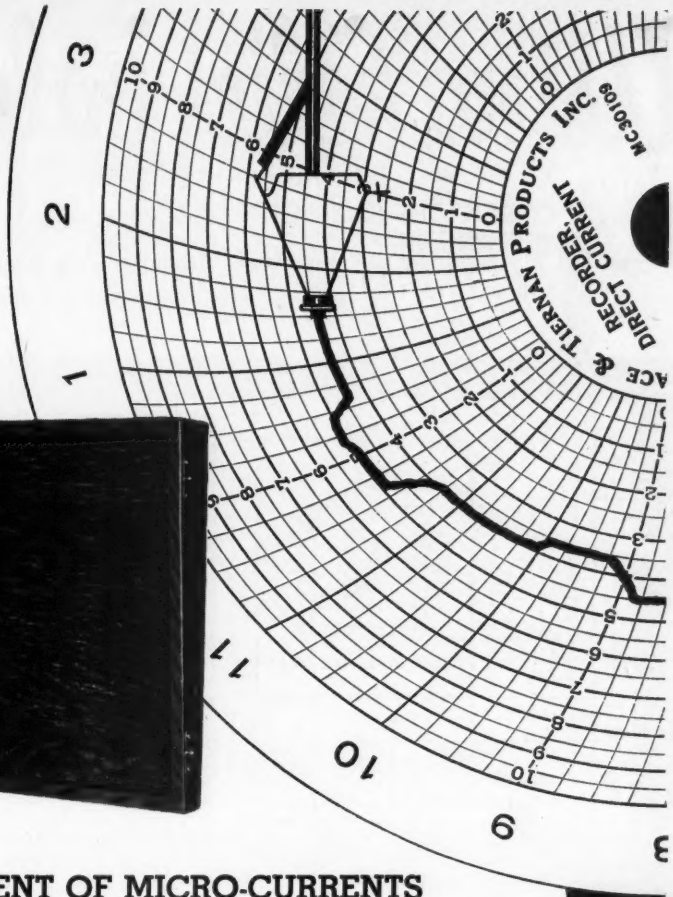
No. 677—1500-pound Welding End Steel Valve for superheated steam service. A.S.M.E. standards with heavy duty handwheel control.

No. 795—Three-inch 3-way Valve Type No. 733 utilizing standard tee and two wafer valves with extended handwheel control.

ANOTHER W&T PRECISION INSTRUMENT

THE PORTABLE DIRECT CURRENT RECORDER





FOR THE MEASUREMENT OF MICRO-CURRENTS

The New W&T Portable Direct Current Recorder permits direct recording of minute electrical currents and voltages, as well as certain non-electrical values through the use of pick-ups and amplifiers. The instrument is extremely versatile and possesses a range whi permits handling 6.0 amperes and, at the same time, can detect a change of current as low as 1/10 microampere. It is useful in research laboratories and for such applications as communication and electronic circuit analysis, and in thermocouple pyrometry. Brief specifications are:

Type	Moving magnet, interchangeable coil.	Scale Length . .	2½ inches.
Sensitivity . . .	1 part in 1000 of full scale range.	Chart Diameter .	8 inches.
Minimum Range .	0 to 100 microamperes.	Chart Speed . .	1 revolution per 24 hours.
Maximum Range .	0 to 6.0 amperes.	Case	Highly finished hard wood.
Coil Adjusting Range . . .	2.3 to 25 ampere turns.	Size	13" high by 10⅛" wide by 5½" deep.
		Weight	10 pounds.

Write today for complete details—there's no obligation

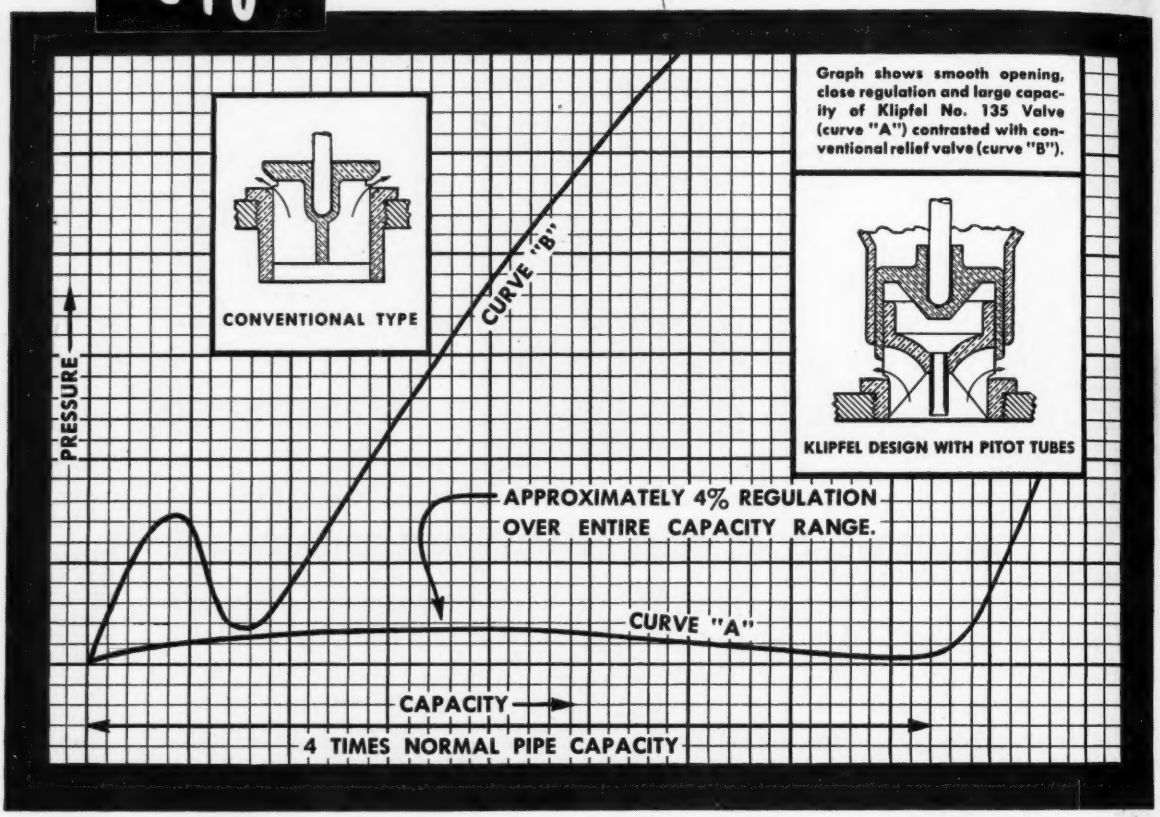
A-87

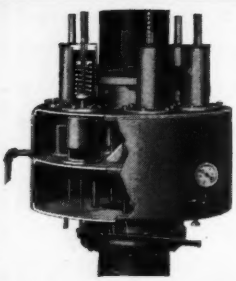
WALLACE & TIERNAN
PRODUCTS, INC.
ELECTRICAL MECHANISMS AND PRECISION INSTRUMENTS
Belleville 9, New Jersey • Represented in Principal Cities

Using relief valves?

CHECK THE PERFORMANCE

OF Klipfel NO. 135 SINGLE and MULTIPORT VALVES


Graph shows smooth opening, close regulation and large capacity of Klipfel No. 135 Valve (curve "A") contrasted with conventional relief valve (curve "B").
CONVENTIONAL TYPE
KLIPFEL DESIGN WITH PITOT TUBES
CURVE "B"
PRESSURE
APPROXIMATELY 4% REGULATION OVER ENTIRE CAPACITY RANGE.
CURVE "A"
CAPACITY
4 TIMES NORMAL PIPE CAPACITY



Single or multiport, the Klipfel No. 135 maintains steam back pressure accurately. Among the features which have made it a favorite with operating and maintenance men are:

INNER VALVE—*an inverted cup slides smoothly on a piston which is integral with the threaded seat bushing.*

EXTERNAL SLEEVE—*an extra feature—permits close regulation with variable outlet pressure by venting spring chamber to a constant pressure source.*

SPRING—*extra long with low spring scale.*

BODY—*in single port, bronze, semi-steel or steel casting. In multiport, all-welded steel plate body.*

PRESSURE RANGE—*single port, up to 300 P.S.I.G.; multiport, vacuum to 20 P.S.I.G.*

PERFORMANCE CHARACTERISTICS

Compensated Spring Loading—
by using fluid velocity.

Tight Closing—
with thin edged seat for low venturi effect.

Chatter-proof Operation—
though inherent dash-pot construction.

Multiport Valves—
open in sequence minimizing wire drawing and improving regulation. Positive testing of each valve with external handle.

FOR FULL DATA on the Klipfel No. 135, write Dept. DA.

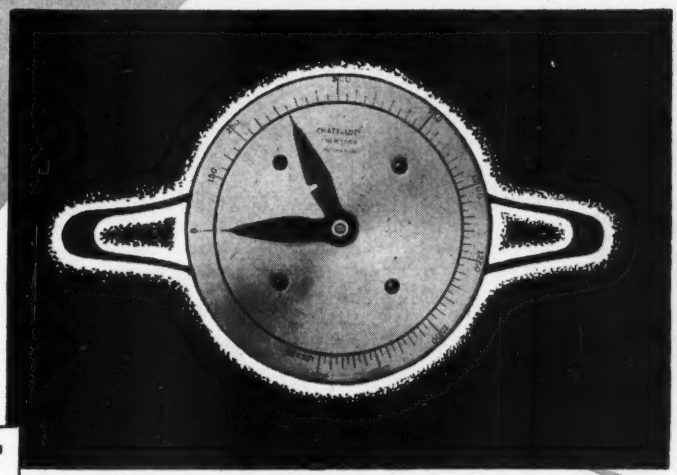
Klipfel VALVES INC.
DIVISION OF
HAMILTON-THOMAS CORP.
HAMILTON, OHIO

WHEN THE PRESSURE OF INDUSTRY IS GREAT...COUNT ON CHATILLON FOR UNFAILING AID!

Since 1835, John Chatillon & Sons have been world famous for the precision manufacture of force measuring devices which meet the most specific requirements of industry.

CHATILLON TRACTION DYNAMOMETERS

- For determining sag in stringing transmission lines.
- To ascertain force required to pull underground cables and wires through conduits.
- For guy wire tensions, pole, insulator and anchor strength.
- For use in conjunction with apparatus that apply force to test strength of materials and structures.
- Gear Mechanism is Enclosed in Dustproof housing.
- Accuracy is Guaranteed to within 2% plus or minus of dial reading.



Traction Dynamometers are made in Capacities shown below:

Capacity & Graduations in lbs.	First Dial Reading lbs.	Dial Dia. Inches	Shipping Weight lbs.
1000 x 10	100	7	8
2000 x 25	150	7	9
5000 x 50	250	8	9
10000 x 100	500	10	15
25000 x 200	600	14	45
50000 x 250	1000	16	56
100000 x 500	1000	18	95

Larger Capacities to Order

FILL IN AND MAIL COUPON TODAY

John Chatillon & Sons, 85 Cliff Street, New York 7, N. Y.

Gentlemen: Please send me complete brochures on

☐ Traction Dynamometers ☐ Push Pull Gauges
☐ Laboratory Scales ☐ Force Measuring Devices

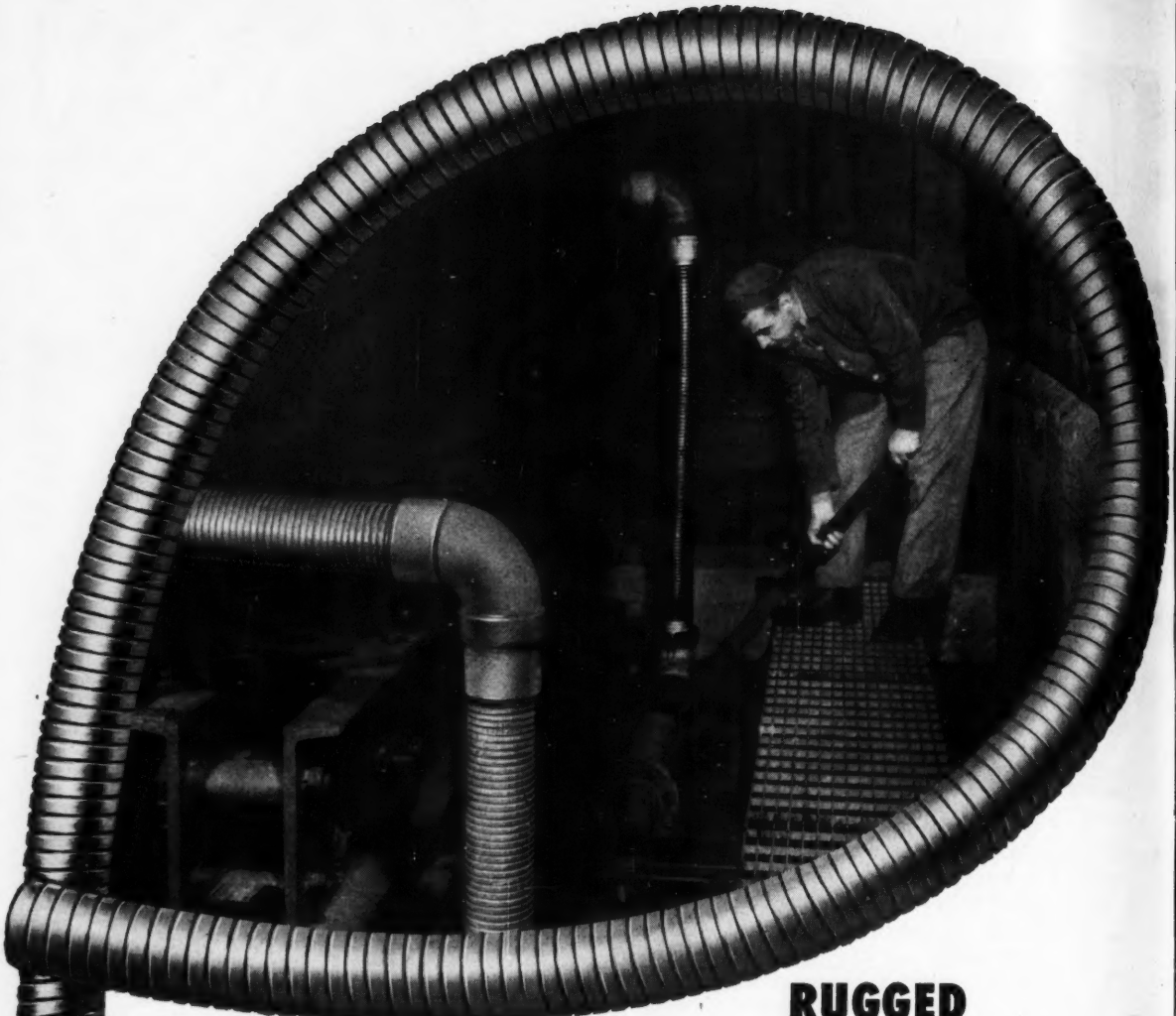
Name.....Company.....

Address.....Position Held.....

JOHN CHATILLON & SONS

85 CLIFF STREET, DEPT. 12, NEW YORK 7, N. Y.

Manufacturers of Precision Instruments Since 1835



RUGGED

FLEXIBILITY FOR EVERY INDUSTRIAL USE

PENFLEX FLEXIBLE METALLIC TUBING is made to meet every requirement of the instrument industry. From ⅛" I.D. to 30" I.D. . . . bronze, galvanized steel, stainless steel or copper . . . from an air compressor line to a diesel exhaust, Penflex makes them all for the instrument industry.

Coast to coast . . . border to border, Penflex installations prove the value of "Flexineering"—the science of applying flexible tubing to fit the particular need of the instrument industry. When you require tubing or hose that is as tight as a pipe but flexible, safe at high temperatures . . . free from metal fatigue . . . specify Penflex.

Penflex manufactures a complete line of four wall interlocked and seamless welded corrugated flexible tubing . . . plus automatic barrel fillers, rivet passers, accessories and fittings. Write for the folder that will help your production—"Flexineering."

Pennsylvania Flexible Metallic Tubing Company, Inc., 7212 Powers Lane, Philadelphia 42, Pa.
Branch Sales Offices: **Boston • New York • Chicago • Houston • Cleveland • Los Angeles**

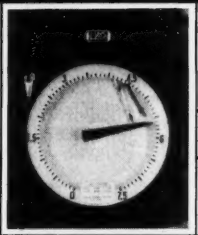
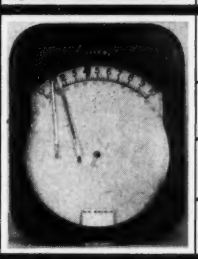
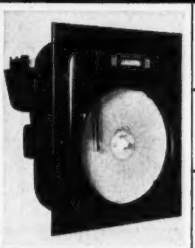
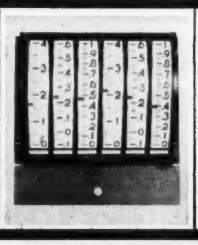
PENFLEX

HEART OF INDUSTRY'S LIFE LINES

Copyright 1951 Penna. Flexible Metallic Tubing Co., Inc.

get results with **HAYS**

in these 5 areas of measurement and control

		type	function	Indicating	Recording	Integrating	Controlling	write for bulletin
1 COMBUSTION CONTROL		Electric type for:					●	
		Boilers {stationary	control of pressure, draft, airflow, fuel feed, and ratio				●	49-605
		marine					●	42-520
		Glass & ceramics furnaces					●	47-842
		Metal heat-treating furnaces					●	48-750
		Open hearths					●	43-586
		Panels	Mounting of boilers & industrial instruments				●	50-773
2 GAS ANALYSIS		Chemical hand (orsat)	measurement of CO, CO^2 & O^2	●				47-668
		automatic	measurement of CO^2	●	●			49-550
		Electronic—automatic	measurement of O^2 and thermal conductivity	●	●		●	50-829
3 FLOW		Mechanical	measurement of steam, liquid, & gas flow	●	●	●		50-915
		Electrical	measurement of steam, liquid, & gas flow	●	●	●		50-800
		Positive Displacement	measurement of liquid flow	●		●		50-766
		Diaphragm	measurement of gas flow	●	●			42-562
4 LIQUID LEVEL		Mechanical	measurement of levels of all liquids —open & closed tanks	●	●			50-915
		Electrical	measurement of levels of all liquids —open & closed tanks	●	●			50-800
		Diaphragm	measurement of levels of all liquids —open tanks only	●	●			42-562
5 DRAFT		Diaphragm	measurement of low pressure, draft, & differential	●	●			50-667
							●	48-606

THE HAYS CORPORATION
MICHIGAN CITY 8 , INDIANA

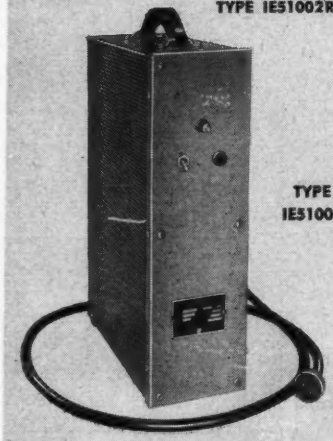
Automatic Combustion Control • Boiler Panels • Hays-Penn Flowmeters
Veriflow Meters and Veritrol • Gas Analyzers • Draft Gages
Combustion Test Sets • CO_2 Recorders • Electronic Oxygen Recorders

FOR MAXIMUM PERFORMANCE AND LONG LIFE OF ELECTRICALLY-OPERATED EQUIPMENT

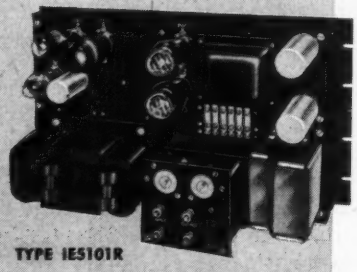
Invest in **STABILINE**

Automatic VOLTAGE REGULATORS

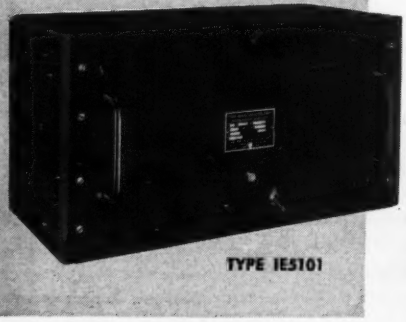
TYPE IES1002R



TYPE IES1005



TYPE IES101R



TYPE IES101

Manufacturers faced with the need for increased production and lower costs are becoming extremely conscious of the importance of maintaining constant voltage to electrical apparatus. The Superior Electric Company's line of STABILINE Automatic Voltage Regulators offers equipment to suit the needs of each application. Two types are available: Type IE (Instantaneous Electronic) and Type EM (Electro-Mechanical).

STABILINE Type IE is a completely electronic unit with no moving parts . . . is used where instantaneous and extremely close correction is required. It maintains a constant output voltage regardless of line variations at no load, full load or any intermediate load. The output voltage is held to within ± 0.1 volts of nominal for wide line variations; within ± 0.15 volts of nominal for any load current change or load power factor change from lagging .5 to leading .9. Maximum waveform distortion never exceeds 3%.

Standard models are available in cabinets or for relay rack mounting in numerous ratings as listed below. In the event you have a special requirement involving other frequencies or ratings, SECO voltage control engineers will study your specific problem and make recommendations without obligation.

INSTANTANEOUS ELECTRONIC CABINET MODELS

Input Voltage Range	Output Voltage Range	Frequency In Cycles	Load Range In Amperes	Load Power Factor Range	Rated Output KVA	Type
95-135	110-120	60 ± 10%	0 - 2.2		0.25	IE51002*
195-255	220-240	60 ± 10%	0 - 1.1		0.25	IE52002*
95-135	110-120	60 ± 10%	0 - 4.5	.5 lagging	0.5	IE51005*
195-255	220-240	60 ± 10%	0 - 2.2		0.5	IE52005*
95-135	110-120	50 ± 10%	0 - 4.5		0.5	IEL51005*
195-255	220-240	50 ± 10%	0 - 2.2		0.5	IEL52005*
95-135	110-120	60 ± 10%	0 - 8.5	to	1.0	IE5101*
195-255	220-240	60 ± 10%	0 - 4.5		1.0	IE5201*
95-135	110-120	50 ± 10%	0 - 8.5		1.0	IEL5101*
195-255	220-240	50 ± 10%	0 - 4.5		1.0	IEL5201*
95-135	110-120	60 ± 10%	0 - 22.0		2.5	IE5102*
195-255	220-240	60 ± 10%	0 - 11.0	.9 leading	2.5	IE5202*
195-255	220-240	50 ± 10%	0 - 11.0		2.5	IEL5202*
95-135	110-120	60 ± 10%	0 - 43.5		5.0	IE5105
195-255	220-240	60 ± 10%	0 - 22.0		5.0	IE5205

*** Also offered in rack models.**

REMEMBER, STABILINE TYPE EM (ELECTRO-MECHANICAL) UNITS ARE ALSO AVAILABLE. RATINGS FROM 2 TO 100 KVA. LITERATURE ON REQUEST.

There's a STABILINE Automatic Voltage Regulator for every need. Send today for literature and specific information. Write The Superior Electric Co., 703 Church St., Bristol, Conn.

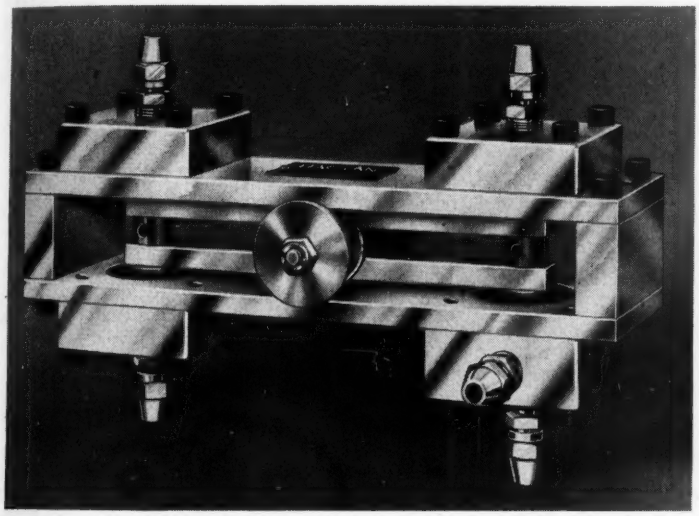
THE SUPERIOR ELECTRIC CO.
BRISTOL, CONNECTICUT

POWERSTAT VARIABLE TRANSFORMERS • VOLTBOX A-C POWER SUPPLIES • STABILINE VOLTAGE REGULATORS

Hagan Ratio Totalizer

UP TO THREE INPUT SIGNALS COMBINED ACCURATELY TO GIVE ONE OUTPUT SIGNAL

Here are a few of the things you can do with this versatile pneumatically-operated automatic control mechanism:



1

Add, subtract or average pneumatic indications of flow rates, to secure a pneumatic indication of the totalized flow.

2

Transmit an output signal which is in a definite ratio to the measured static pressure.

3

Establish a remote pneumatic set point adjustment, or introduce rate of change or automatic reset characteristics into an automatic control system.

4

Establish a wide variety of selector or limiting control actions, by using Totalizer units singly or in multiple.

For detailed information concerning this extremely versatile mechanism, just fill in and mail the coupon or write to Hagan Corporation, Hagan Building, Pittsburgh 30, Pa., giving details of any specific application in which you are interested.

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RING BALANCE FLOW AND PRESSURE INSTRUMENTS
THRUSTORQ FORCE MEASURING DEVICES
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METALLURGICAL FURNACE CONTROL SYSTEMS

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I-3

WHY RISK THIS TO SAVE A DIME A WEEK?

The scrap pile of many a plant—whether it makes gears, bricks or gummed tape—thrives on poor temperature control. And the margin is often narrow . . . a variation of only a few degrees meaning thousands of dollars in rejected material or damaged equipment.

Yet many plants risk this loss without realizing it! They attack the temperature control problem correctly, by using potentiometer pyrometers to get top accuracy and dependability. But they sometimes slip on the "standardizing" adjustments which such instruments need to maintain those qualities. Overlooking the need for frequent and regular standardizing, these plants permit the operation to be done by hand . . . and thus possibly skimped or forgotten.

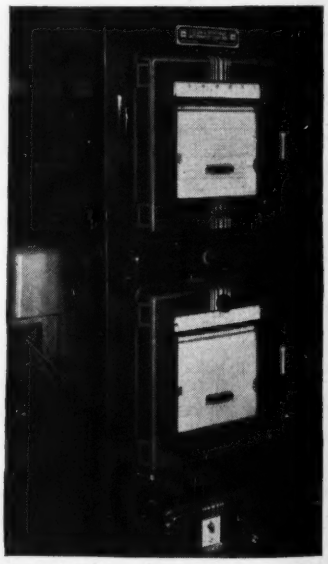
There is just one way of removing this threat to the accuracy of process temperature. It's by putting the standardizing responsibility where it belongs . . . directly on the recorders and controllers themselves.

A relatively simple device, the automatic standardizer, should be built into the potentiometer to handle this job. It checks the measuring circuit at least every 48 minutes . . . adjusts when necessary . . . *never forgets!* And this essential feature, amortized in the usual 10 years, costs less than 10¢ a week.

So, regardless of what make instruments you buy, be sure to specify automatic standardizing. It's cheap . . . safe . . . sure!

Write Leeds & Northrup Company, 4955 Stenton Avenue, Philadelphia 44, Pennsylvania.

AUTOMATIC STANDARDIZING Guards Product Quality When You Use Instruments Like These



Speedomax Potentiometer Instruments and Drive Unit (left) helping maintain production in an Ohio metal-working plant.

Jrl Ad ND4(3)

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

8719 New Instruments

BELOW is reproduced a tabulation of new instrument items which have appeared in *Instruments* each year during the 23 years it has been published.

Year	New Instruments	Progressive Total	No. of companies listed in the *Instruments Index*
1928	84	84	
1929	106	190	
1930	133	323	
1931	233	556	
1932	283	839	
1933	308	1147	
1934	311	1458	
1935	306	1764	692
1936	317	2081	
1937	313	2394	
1938	370	2764	
1939	363	3127	854
1940	291	3418	843
1941	246	3664	933
1942	266	3930	964
1943	280	4210	1013
1944	312	4522	1044
1945	393	4915	
1946	647	5562	1264
1947	660	6222	1307
1948	636	6858	
1949	798	7656	1361
1950	1063	8719	

A new instrument, as defined by *Instruments*, is any device which measures, inspects, tests or controls; or any product, which is an accessory or allied product, made by the manufacturer for the first time. Further a considerable change in the design or construction of an instrument also qualifies the product for inclusion in the "New Instruments" Section.

In the case of foreign new developments, these are only **included** if they are available through an office or representative in the United States.*

A very interesting phenomena can be noted in the above table. Omitting the years from 1928 to 1931, which was a period during which the list of instrument manufacturers was being assembled, it will be noted that the annual number of new instruments from 1932 to 1945 inclusive is about 300. From 1946 to 1948 inclusive the annual number went up slightly above 600. In 1949 the number went up to 800 and to 1000 in 1950.

During this period the number of instrument manufacturers increased. The first year that there was any indication of the number of companies in the Instrument Industry was in 1935 when the first *Instruments Index* appeared. The number of companies listed in that *Index* was 692. In the above table, column 4 shows the number of companies listed in subsequent issues of the *Instruments Index*. By 1949, the number was almost double the number in 1935. This increase is confirmed by the 1947 Census of Manufactures as compared with the 1939 Census:

	No. of Establishments Reporting in 1939	1947
Scales and Balances	56	75
Measuring and Dispensing Pumps	38	52
Electrical Measuring Instruments	59	154
Scientific Instruments	125	216
Mechanical Measuring Instruments	227	463
Optical Instruments and Lenses	31	114
Totals	536	1074

It is also interesting to note the Instrument Industry appears as a separate industry in the 1947 Census of Manufactures. For the first time the Instrument Industry was recognized by establishing code number 38 as "Instruments and Related Products." Even so there are still a number of Industries not included in this code but which are very definitely a part of the Instrument Industry. In the 1939 Census of Manufactures, the Instrument Manufacturers were reported as a part of the Miscellaneous industries. In the War Production Board during the Second World War instrument products were distributed among 22 of the 40 divisions.

For National Defense purposes, Instrument Manufacturers should be classified as mechanical, electrical, optical, etc. rather than as scientific or industrial. A scientific instrument is an instrument for which there is a small demand; when the demand increases it has become an industrial instrument.

Further all precision working industries should be assembled in one division in the National Production Authority as these industries represent a large number of man-hours per pound of material. Such a set-up will solve the most serious difficulty of the instrument industry—obtaining the necessary amount of raw material.

*This is correct statement of policy on foreign-made instruments. On page 203 of our February issue, a typographical error resulted in a serious misstatement of policy.

Errors Introduced *into* F-M CARRIER MEASURING SYSTEMS *by* Time-base Variations *in* Recording *and* Reproducing Data

By DR. JAMES C. COE, Edwards Air Force Base, Muroc, California

SUMMARY—In the field of dynamic measurements, the use of alternating currents in the audio and supersonic frequency ranges as carriers for low-frequency intelligence has been extended in recent years to frequency-modulated systems. Some of these use several frequencies in multichannel systems. Recording the intelligence after its separation from its carrier requires a time-base accuracy somewhat better than the capabilities of the system, with respect to the time resolution which the system is capable of giving the intelligence frequency.

In some applications it is desired to record the composite signal, in which the intelligence has not ben separated from the carrier. This is an interim step, to be followed later by playing the recording back into the discriminator, from which the intelligence emerges devoid of carrier. It was found that the difference between recording speed and playback speed can cause serious errors in the amplitude of the intelligence when recorded with the carrier. Unless this difference is accurately known and used as a correction, or some means applied for its compensation, misleading results are inevitable.

Measurements of speed variations of various recorders and so called constant-speed motors were made. A formula was developed and the amplitude errors resulting from speed differences between the recordings or playback of a frequency-modulated composite signal were computed.

AMPLITUDE-MODULATED audio-frequency carrier systems are used where relatively short distances separate the physical quantities to be measured and the remainder of the equipment, or where the extraneous noise picked up is inconsequential. These carrier systems are commonly employed with non-generating type pickups such as strain gages, or accelerometers, displacement, force and pressure pickups of the strain-gage-bridge principle. They are less useful where there is stray electrical interference, where a great distance intervenes, and electrical noise becomes a factor to limit the ultimate accuracy of an a-m. system. It is under such conditions, or where a radio link is interposed, that a frequency modulated system finds its greatest use.

In the f-m. carrier system, a change in the magnitude of the physical quantity to be measured is translated into a change in carrier frequency. The dependence of amplitude upon frequency is inherent in frequency modulation. The accuracy of the amplitude of the data recorded by this system depends upon the accurate conversion of these frequency changes into amplitude changes. The end result after separating the intelligence of each channel from its carrier, as recorded by a multichannel oscillograph, for example, appears as amplitude versus time on the chart.

The opinions and assertions contained herein are the private ones of the writer, and are not to be construed as official or reflecting the views of the Defense Department or the Service at large.

The recording may be accomplished at any of three locations in the carrier system. The first is with a group of carriers, and the intelligence they convey, all combined as a composite signal.

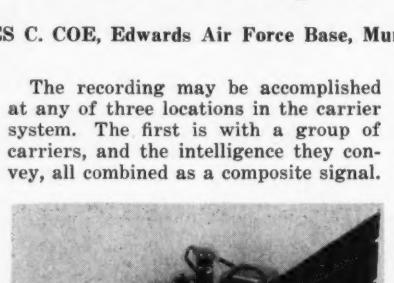


Fig. 1. Piezoelectric 60-cps. source.

The second is after the carriers have been separated into individual channels each carrying its intelligence. The third point to record data is after the separation of the intelligence from the carrier, where each signal emerges in the same general form as when it was impressed upon the carrier.

It was found that the requirements imposed upon the recording equipment differ greatly with each of these three methods, and serious errors can result from small changes in the time base, using the first two methods. Existing recording methods have been examined as to their suitability, first with respect to band width, and second with respect to time-base. It was determined that an extremely accurate time-base was imperative if the amplitude errors in the first two methods were to be kept under 1 percent, since a small time-base error resulting from the recording at either of the first two points in the circuit will cause a much larger amplitude error. Time-base variations with the third method of recording do not introduce amplitude errors. With some recorders speed is the time-base.

More accurate data is possible if the intelligence is recorded after it has been separated from its carrier, since each transformation adds errors. The recorders most commonly used for recording dynamic measurements are of two general types, both of which respond down to zero cycles. The direct printing of stylus type recorders are not satisfactory if frequencies exceed about 100 cps. Another type utilizes sensitive galvanometers, each equipped with a mirror, and the light beam traverses sensitized paper which is run from the supply reel to the takeup reel. Multi-channel recording oscillographs

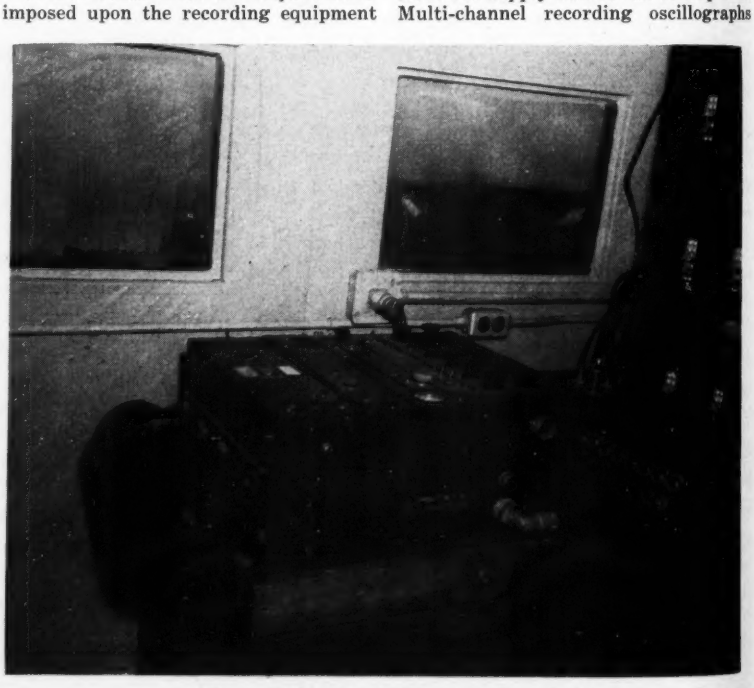


Fig. 2. Hathaway multi-channel oscillograph.

are shown in Figs. 2 and 3. Timing lines across the paper originate from a tuning fork or oscillator. Another type utilizes a camera to photograph one or more cathode-ray tubes. Lamps flashing at known rates such as 10 and 100 times per second, are often used to furnish the time-base to the film if the motor speed is not in itself adequate.

There are various reasons for recording a composite signal from one or more carriers which have been frequency-modulated by intelligence, resulting from physical quantities which it is desired to measure. While the above recorders are portable and rugged to a degree, there are magnetic-type audio-recorders which can withstand far more rigorous treatment than the galvanometer type. The response of magnetic recorders under 20 cps. is inadequate for many physical quantities which may at times vary much slower than 20 times per second. However, the frequency response of magnetic recorders may be satisfactory for the audio-frequency carriers. Situations occur where it is not convenient to record on sensitized paper or film, or where risks associated with handling and transporting such records before developing do not exist with magnetic or disk records. Cost may be a factor where data is transmitted simultaneously over a large number of channels and requiring a number of recorders. The recorders shown in Figs. 2 and 3 cost approximately $350 per channel. They require skill in their operation and maintenance. Sensitized paper or film is expensive compared to magnetic wire or tape. Using a number of inexpensive recorders and then transcribing all the data into a limited number of oscillograph recorders for final presentation of all intelligence has the advantage of providing a convenient means of presentation for comparison.

The errors introduced by recording the composite signal at one speed, and playback at a slightly different speed may be very large, and it is therefore imperative that they be kept from exceeding permissible values. The primary purpose of this article is to discuss errors introduced due to variations in time-base, particularly those errors due to the difference between recording and playback speeds.

Measurements of time-base variations of various recorders and reproducers, and the speed of so-called constant-speed motors were made. A theoretical study of errors on measurements resulting from such variations was made with the recording accomplished at various points in the decoding process. The above study and measurements were made of the time-base, or what is often synonymous, namely, the speed variations of existing equipments, to determine the effect of the lack of constancy on time sequence studies, and on amplitude accuracy, and to prescribe the extent to which such variations are permissible in holding resulting amplitude errors to 1 percent.

It is not within the scope of this article to present a complete description, or the detailed operating characteristics of the various recorders, but to present some of the salient points relative to the subject. Nor is it the purpose to present all the data, but only a minimum, resembling a synopsis rather than a complete treatise. Illustrations by specific example rather than by means of a more involved treatment have been employed. Amplitude errors caused by variations in the time-base of three recording locations in f-m. carrier systems are presented.

DIRECT RECORDING OF INTELLIGENCE:

In an f-m. system, an amplitude change in the quantity being measured

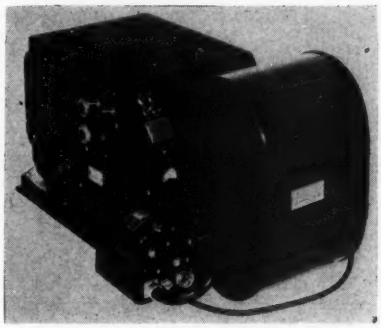


Fig. 3. Consolidated multi-channel oscillograph.

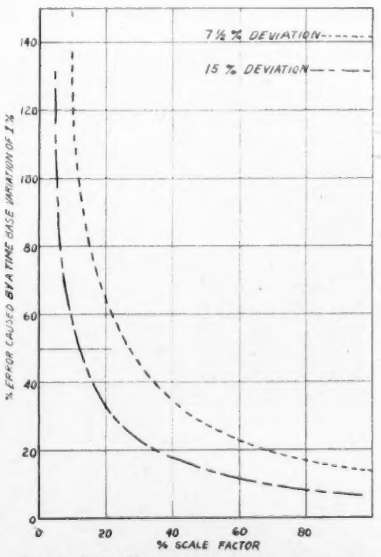
produces a change in the unmodulated quiescent or center carrier frequency, and is referred to as the frequency deviation. It is the numerical value of this change in frequency, which varies with the amplitude of the intelligence from zero to maximum. If the physical quantity takes a fixed value, the frequency assumes a corresponding value. This change in frequency would be translated by the discriminator into a change in the position of a spot of light in the recording galvanometer type of instrument shown in Figs. 2 and 3. If, however, the amplitude of the physical quantity varies cyclicly at a rate, known as the modulation frequency, the carrier frequency varies at a similar rate, but by a greater amount. In this case the spot of light would move at the modulation frequency. Such a recording is in a usable form. The rate at which the paper travels, and the accuracy of the timing lines have no effect upon the amplitude of motion of the light beam, or upon the final reading as transcribed from the record.

If several such channels are thus recorded simultaneously on the same roll of paper, only the errors in correlating time sequences of events will be caused by variations in the time-base. In making time sequence studies however, it must be considered that the great majority of the pickups and often the physical quantities have in themselves time delays due to their respective mechanical inertias, temperature lags, etc. When recording the amplitude and frequency of the intelligence, time-base errors affect only the accuracy of time studies, including the total elapsed time. The frequency response required of the recorder ranges from zero to the maximum frequency of the intelligence, which in turn is limited by the bandwidth of the channel.

RECORDING THE COMPOSITE SIGNAL:

Another method is to separately record the individual modulated carriers, each of which carries its own intelligence. The bandwidth required of the recorder is equal to the center frequency of the carrier plus and minus the frequency deviation which is due to an increase or decrease in the amplitude of the intelligence. A 2000-cps. carrier center frequency with a 7.5-percent deviation caused by the intelligence requires a bandwidth of 1850 to 2150 cps. of the recorder in order to respond to amplitude extremes.

As an example, let it be assumed



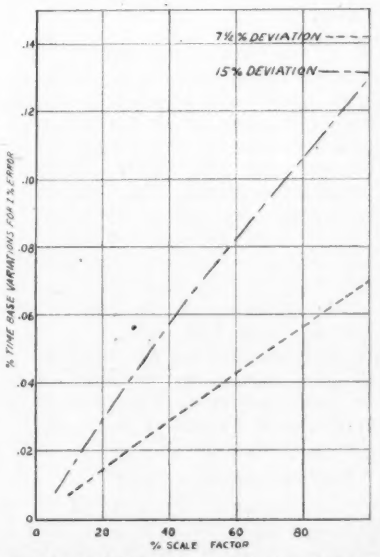


Fig. 4. (left) Percentage of error caused by a time-base variation of 1 percent, as a function of scale factor. Fig. 5. (right) Time-base variations for 1 percent error as a function of scale factor.

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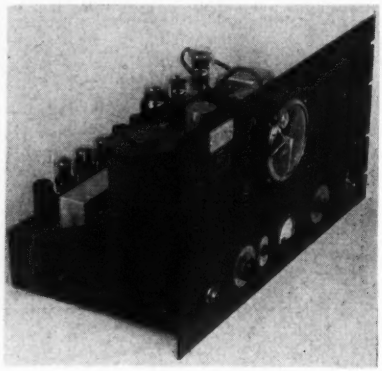

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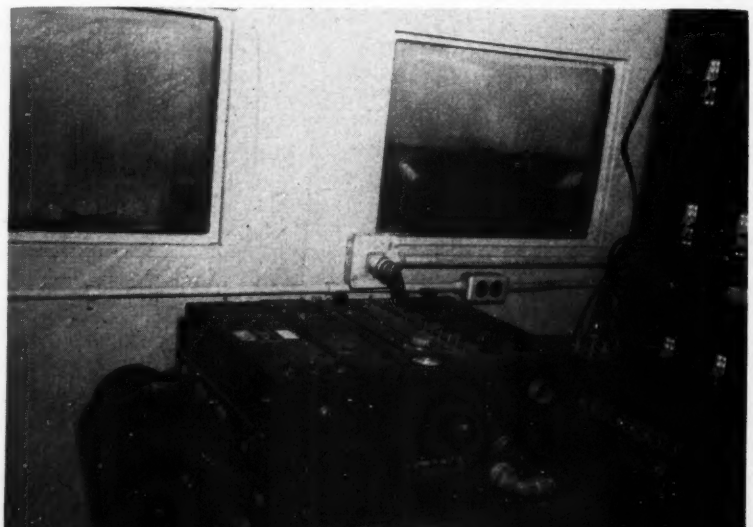

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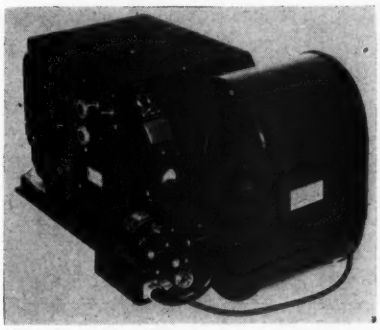


Fig. 3. Consolidated multi-channel oscillograph.

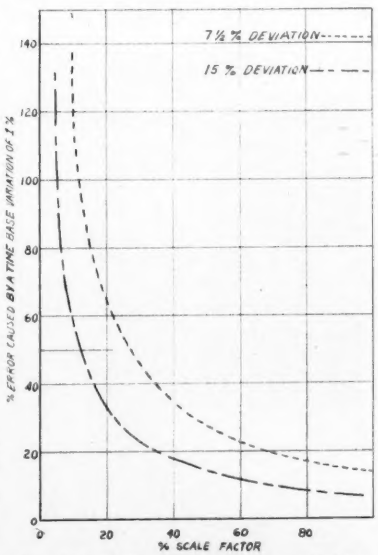
produces a change in the unmodulated quiescent or center carrier frequency, and is referred to as the frequency deviation. It is the numerical value of this change in frequency, which varies with the amplitude of the intelligence from zero to maximum. If the physical quantity takes a fixed value, the frequency assumes a corresponding value. This change in frequency would be translated by the discriminator into a change in the position of a spot of light in the recording galvanometer type of instrument shown in Figs. 2 and 3. If, however, the amplitude of the physical quantity varies cyclicly at a rate, known as the modulation frequency, the carrier frequency varies at a similar rate, but by a greater amount. In this case the spot of light would move at the modulation frequency. Such a recording is in a usable form. The rate at which the paper travels, and the accuracy of the timing lines have no effect upon the amplitude of motion of the light beam, or upon the final reading as transcribed from the record.

If several such channels are thus recorded simultaneously on the same roll of paper, only the errors in correlating time sequences of events will be caused by variations in the time-base. In making time sequence studies however, it must be considered that the great majority of the pickups and often the physical quantities have in themselves time delays due to their respective mechanical inertias, temperature lags, etc. When recording the amplitude and frequency of the intelligence, time-base errors affect only the accuracy of time studies, including the total elapsed time. The frequency response required of the recorder ranges from zero to the maximum frequency of the intelligence, which in turn is limited by the bandwidth of the channel.

Recording the Composite Signal:

Another method is to separately record the individual modulated carriers, each of which carries its own intelligence. The bandwidth required of the recorder is equal to the center frequency of the carrier plus and minus the frequency deviation which is due to an increase or decrease in the amplitude of the intelligence. A 2000-cps. carrier center frequency with a 7.5-percent deviation caused by the intelligence requires a bandwidth of 1850 to 2150 cps. of the recorder in order to respond to amplitude extremes.

As an example, let it be assumed



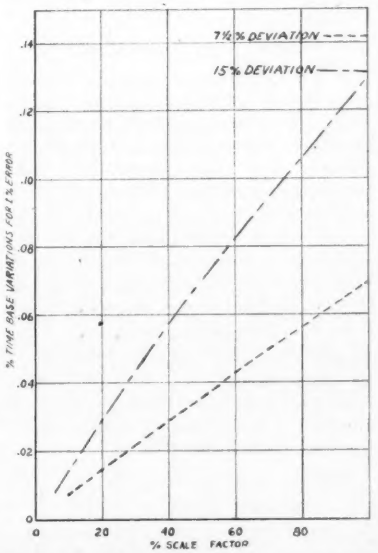


Fig. 4. (left) Percentage of error caused by a time-base variation of 1 percent, as a function of scale factor. Fig. 5. (right) Time-base variations for 1 percent error as a function of scale factor.

that by the use of this method of recording, an increase in the quantity of one-third its maximum will cause the carrier frequency to shift from 2000 to 2050 cps. A variation of 1 percent in the speed of the wire, tape, or disk between recording and playback speeds, will represent a change of 20.5 cps. The variation in the physical quantity has produced a change of 50 cps., and 20.5 cps. represents an error of 41 percent.

If the 50 cps. resulted from a 100-lb. change in pressure, a variation in recording speed of 1 percent, and an additional variation of 1 percent in reproducer speed, will cause an additional error which might add to or cancel out the error caused by the variation in the speed of the recorder. Therefore, with individual variations of 1 percent the data thus recorded could range from 18 to 182 lbs., instead of the true-value 100 lbs. The error increases as the pressure in the above example decreases.

Thus in the recording and reproducing of an f-m. carrier, a small variation in time-base can produce a larger error in the data. For accurate results, the speeds must either remain constant, or must vary by the same amount simultaneously, and in the same direction, or the speeds must be accurately known and taken into account during the process of data reduction, or a correction factor must be obtained which is a function of the speed difference.

If all the carriers are still mixed when recorded, the bandwidth required to record the composite signal will extend from the lowest carrier frequency to the highest, and will include the maximum deviation due to modulation. The various carriers must be separated by filters before being fed into their respective discriminators. Errors in the data caused by time-base changes with such an arrangement are the same as if each carrier is recorded separately.

THEORETICAL DISCUSSION:

In recording f-m. carriers, variations in time-base cause errors in amplitude. The error varies (a) directly with time-base variations, (b) approximately inversely with scale factor (the scale factor is the portion of the total deviation frequency caused by the individual measurement under consideration), (c) approximately inversely with the deviation; and (d) the error at any instant is independent of the modulation frequency. Upon this basis the error in amplitude, caused by variations in the time-base of the recording or reproducing processes, may therefore be expressed in terms of frequencies and the scale-factor, namely,

$$\text{Percent Amplitude Error} = \frac{f_e}{f_d s}(100) = \frac{(f_e + f_d s)\ (\text{time-base variation in } \%)}{f_d s}$$

where: f_c = carrier center frequency
f_d = full scale deviation frequency which is plus or minus with respect to f_c.
f_e = frequency change caused by the difference in speed between recording and reproducing a carrier.
s = scale factor or part of full scale deviation frequency caused by the physical quantity.

In the example cited, where the time-base variation was one percent, f_c was 2000 cps., f_d was 150 cps. and the frequency change caused by 100-lbs. change in pressure was plus 50 cps., and the scale factor was one third. If conditions required only a 100-lb. change, and if the pickup was so modified that this change caused a deviation of the full 150 cps., the error would be about a third as much as with 50 cps. deviation. It is evident that the range should not be extended beyond the maximum needed, and also that the nearer a reading is to full scale or maximum deviation, the less the error will be due to time-base variations. Errors because of time-base variations would be approximately half as much for a carrier system having a maximum deviation of 15 percent, than for a system in which the maximum deviation is only 7.5 precent.

Fig. 6. Harmonic amplifier panel.

There are equipment limitations which restrict the maximum deviation. There is also the consideration that with a greater deviation, there must be a greater separation between carriers, or the harmonics of the lower f-m. carriers will cause cross modulation products to be present in the higher carriers.

Fig. 4 is a graphical presentation of the percent error caused by a time-base variation of one percent, versus various scale factors when recording a carrier frequency. One curve is for a maximum deviation of 7.5 percent, and the other is for a maximum deviation of 15 percent. In either case if the percentage of full scale values decreases, the error increases likewise.

In Fig. 5 are shown the variations in the time-base as plotted against percent scale factor if the time-base variation in recording and reproducing the carrier is to be kept to 1 percent. It is evident that with a scale factor of 10 percent, time-base variations should be held to about 75 parts in a million to keep this error down to 1 percent, with a deviation of 7.5 percent. Similarly with a scale factor of 1 percent, time-base variations should be kept below 7 parts per million. This precision is not feasible with recording means now available. The recording of certain tests involves motion of film, paper, wire, magnetic tape, or disks. Even if the speed of the driving motor could be made sufficiently constant, there would remain the mechanical problems involving means of driving, and the difficulties incidental to mechanical motion, such as film, wire, or paper slap.

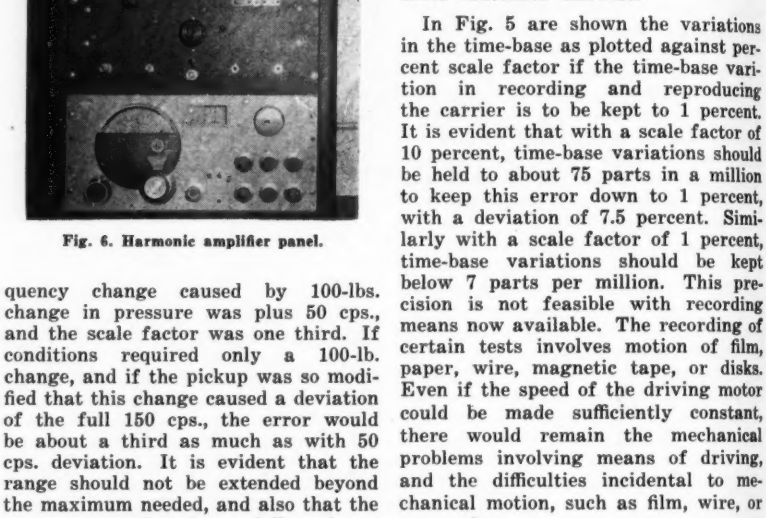


Fig. 7. Section of audio-frequency laboratory.

Method of Measurement

In general, the method used to measure speed was to convert speed to an audio frequency, then to heterodyne the signal with an accurate frequency source. The resultant number of beats per second was numerically equal to the difference in the component frequencies. Where the difference was small, Lissajous figures were shown on the screen of a cathode-ray tube and counted. Instantaneous variations of speed were obtained from recording type galvanometer records.

In order to measure variations in recorder speed, the output of a piezo-electrically-controlled oscillator, shown in Fig. 1 was recorded. The error of this oscillator was less than 5 parts per million which would integrate into about 0.5 second in 24 hours. Commercial power was supplied to the recorder, the voltage of which was regulated electronically. Recordings were made at the ends and intermediate position of the record. On playback the reproduced signal was heterodyned with the oscillator, and the resultant beat frequency was translated into terms of speed variations as outlined.

The accuracy of the timing lines of multichannel recording oscillographs was measured by heterodyning the timing frequency with an accurate frequency standard. Another method used was to mix both frequencies and to record the resultant beats on one of the channels. An Amglo d-c. motor shown in Fig. 8, embodying vibrating reed control in its design, was tested for speed variations. A tone wheel was attached to the motor shaft, and the audio frequency of the tone was compared with that of an accurate frequency source.

Transmissions from radio station WWV, operated by the National Bureau of Standards, were used as the primary frequency standard. A harmonic amplifier shown in Figs. 6 and 7 was used to transform the 440-cps. audio note of WWV radio transmissions into 660, 880, 1100, 1320, 1540, 1760, 1980, 2200, etc. cps.[1] In order to determine frequency variations of commercial power, the latter was fed into the harmonic amplifier, and the twenty-second harmonic, namely, approximately 1320 cps. was heterodyned with the third harmonic of WWV audio transmissions. The accuracy of WWV transmissions is of the order of 1 in 30 million. This accuracy cannot be entirely realized if there is selective fading of the modulation, or if problems presented by heterodyning varying frequencies should be encountered.

D-c. Motor Speed

D-c. motor drive was examined since a d-c. motor is used in one type of magnetic tape recorder. In this design a timing wave is used to correct motor speed, but is subject to a time delay in its application. A d-c. motor of novel design having good speed characteristics was also examined, namely, the Amglo motor. The speed of the Amglo motor, is in effect controlled by a vibrating reed at the rate of 15 times per second. This motor is perhaps the nearest d-c. approach to a synchronous motor. While its speed characteristics are very good, its speed is somewhat dependent upon input voltage, although the variation is only 0.28 percent from 11 to 12 volts. A curve of speed versus input voltage is shown in Fig. 9. It is roughly comparable to a lightly loaded induction motor having good torque-slip characteristics.

Synchronous Motor Speed

These motors have excellent speed characteristics as their speed is a direct function of frequency, unless they are operated with a very low voltage or an excessive load. Tests have proven that the frequency of commercial power is subject to some changes, although the average over a period is very good. Governors are intricate and sensitive to frequency changes, but there is an inherent lag in their operation due to the enormous inertia of the rotating system of the power generating equipment. The fundamental principle of governor operation is that a frequency change must first take place before the governor can restore the desired frequency. A quartz-crystal oscillator such as shown in Fig. 1 can supply a control of frequency. The crystal frequency has been reduced by frequency subdivision methods to that of the a-c. motor. Phase shifting networks capable of delivering currents displaced in phase followed by power amplifiers would permit polyphase synchronous-motor operation. The problems then remaining are mechanical, involving drive mechanisms, and film or paper slap, etc.

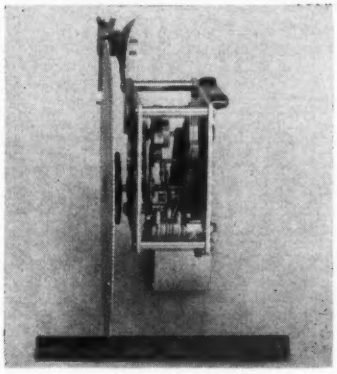


Fig. 8. Amglo motor.

Ribbon-light Valve Recorders

The Western Electric Co. "Mirragraph" belongs in this classification. With this equipment thirteen channels may be recorded on 35 mm. film. Viewing the record does not yield usable data, and since the reproducer output is electrical, there must be another transformation for the information to be viewed on a chart. The maximum range of frequency response is from 0 to 6000 cps., which is not high enough for recording the higher carriers, but is adequate for most intelligence frequencies. In this equipment, synchronous motors are used for film drive. An eddy-current drag is used to reduce film slap, but the film speed is only guaranteed to 0.2 percent. This variation of film speed is tolerable for recording the intelligence directly.

Recording of Meter Indications

If the intelligence of each channel is presented by means of meter indications, the dials are then photographed and later projected for study. A flasher lamp system may be used to give indications of time divisions. If a lamp is photographed through the lens, it will appear at the same location on each frame, as it may have flashed at any time during the exposure of a frame. If a relatively high flashing rate is used, it may flash while the shutter is closed, hence no record of flash would be recorded. This type of timing would obviously complicate data reduction problems. A more satisfactory method is to photograph a clock. Synchronous timers are available which indicate elapsed time to one millisecond, but the one hand revolves so fast that either the film must also be run through rapidly, or a flasher lamp must periodically illuminate the face of the clock. The accuracy is dependent upon the line frequency, and upon the time required to start and stop the rotational mechanism. In one model, electronically-controlled electromagnetic brakes are used to obtain an accuracy of 0.5 millisecond during any one run. The damping of meters however, is so near critical, that such rapid changes in the quantities being measured cannot be registered by the meters.

An alternative method of using a flasher lamp is to place the lamp so that the light impinges upon the film at a point displaced from the film gate, where the film is always in motion. A more accurate way of accomplishing this is to use a camera employing a sound track, where the film in one location is made to move at a fairly uniform rate. The time between the flash and the frame being exposed at the time of flash, must be taken into consideration when the data is taken from the film.

Measurements were made on various motion picture cameras, including spring-driven types. It was found that the speed decreased with time of operation, and in an extreme case the speed decreased to 76 percent of the initial speed. The speed of motor-driven cameras reflects the characteristics of the motor and governor. While instrument panels have actually been photographed by some organizations, this method is characterized by having an extremely low time resolution because of the slow response of the meters.

Recording Oscillographs

Multichannel recording oscillographs as shown in Figs. 2 and 3 are generally used in recording the intelligence. Maximum paper speeds are 40 and 48 inches

1) James C. Coe, "Measuring Speed by Means of WWV," *Electronics*, August 1948.

per second in the types shown in the photographs. A tuning fork is used on one model as a time-base, and the electrical output of the fork drives a vibrating type of inverter which supplies the a-c. to the single-phase synchronous motor driving the timing drum. The speed of the timing drum is thus independent of paper speed. While the tuning fork is supposed to be accurate to 0.01 percent, occasional adjustments are required. One was found to be 0.016 percent fast, and another 0.067 percent slow. A more accurate timing wave could be impressed on one of the spare channels, but much of the advantage would be offset by paper shrinkage caused by the developing process. A separate source for the timing lines can be made available instead of the self-contained tuning fork or oscillator.

Disk Recorders

The disk recorders which were tested were operated at about 33 rpm., cutting 105 grooves per inch from the center outward. The speed of the disk on playback was higher than on recording because of the difference in load presented by the cutting head from the pickup. A difference in speed was also found to exist between the beginning and the end of the record. The following are typical readings:

Location on Disk	*Percent Speed Difference* *Make No. 1*	*Make No. 2*
Center	2.3	1.9
Intermediate	4.5	3.5
Outside	8.0	5.4

At below-normal voltages the frequency differences were greater than at the rated voltage when induction motors were used. These differences were due to motor regulation and drive losses which are accentuated by the difference in diameter. Because of inertia effects, a heavy turntable is less subject to rapid changes in speed. The use of lightweight turntables is dictated by the industry's requirements for rapid starting and stopping, and at the expense of speed stability. Disk recorders are not satisfactory for the recording of the usual intelligence frequencies because of their poor response at low frequencies. They are therefore limited to functions having higher frequencies, or to the recording of f-m. carriers. Used in this manner the speed variations of disk recorders would cause enormous amplitude errors, therefore, a timing frequency would have to be added and utilized on playback.

Magnetic Recorders

Some makes of magnetic recorders employ a synchronous motor which has no slip, and has other advanced design features. The results of a number of measurements taken with such recorders show speed variations of 0.5 percent. The measurements were taken at the ends as well as at intermediate points on the reel. Magnetic recorders do not respond to the lower frequencies and are therefore subject to the same limitations as disk recorders.

Cathode-ray Tube Recorders

These recorders have the widest pass band of any since the only mechanical system involved is in the camera. The spot is caused to move back and forth on the face of the cathode-ray tube, and the continuous motion of the film produces the time axis. No shutter is used in this type of camera, and maximum speeds up to 94 ft. per sec. are obtainable in commercial models. A dual-beam tube with electronic switching would permit the recording of 4 traces per tube. A single camera can

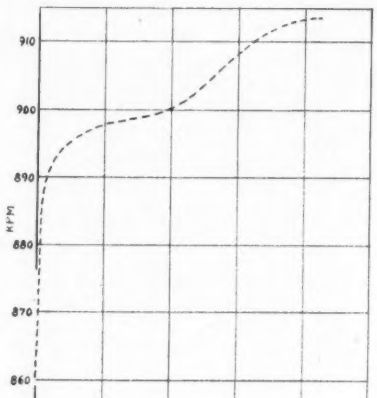


Fig. 9. Amglo motor-speed vs. input voltage.

be used to photograph several tubes, and such a complete instrument is commercially available. The use of more than one camera adds to the time sequence problems because the time-base must be referred from one film to another. The possible time-bases used are motor speed, and timing marks. The latter have advantages of being accurate and convenient for data reduction.

By this method, intelligence, or the carriers can be recorded. The problem of mechanically separating the intelligence from the carrier as presented on such a record remains to be solved. In other words there is no means of playing back such a record.

Printing Recorders

A recorder was tested and found to vary as much as 4 percent in speed. The maximum speed is about 5 in. per sec. The maximum frequency response is about 100 cps., which is adequate for some data recording purposes. These recorders are available with up to 6 channels for multichannel work. One channel can be used to record an accurately known frequency to bring about a slight improvement in time-base.

Conclusions

From the standpoint of time sequence studies, many existing recording means have a fairly accurate built-in time-base. For example, recording oscillographs having timing lines accurate to 0.01 percent are sufficiently accurate for most purposes. On the basis of 100 seconds of operation, this would represent a total time error of only 0.01 second. On the basis of 100 cps., it would represent 0.01 cycle. There is a direct relationship between the bandwidth of the channel and the accuracy required of the time-base. In order to utilize improved time resolution in the pickup, a wider band is required of the remainder of the equipment. The speed of the paper is also a factor in realizing the full capabilities of bandwidth and time-base accuracy, as paper speed also limits the effective time resolution. Unless the paper speed is adequate, it is impossible to determine at what precise time a trace changes its slope, or to reach the absolute peak value. A wide coarse trace also makes it difficult to detect the precise instant that these things happen.

A time history of the variation of the physical quantities is distorted if excessive speed variations exist between the recorder or reproducer speeds. Accurate determinations of frequencies of the order of several hundred cycles per second, or the correlation of reaction time of quantities which change in less than 0.01 second, demand a corresponding channel bandwidth, recorder response, paper or film speed, and time-base accuracy. Such recorders must have a response from zero to the highest intelligence frequency.

One of the greatest sources of amplitude error is to be found in time-base variations in the recording and reproducing of f-m. carriers. Speed is the usual time-base in most recording and reproducing devices unless augmented by another time-base. Speed changes may be gradual in nature, pulsatory, or a combination of the two. Pulsating changes are particularly difficult to take into account when applying corrections to data which has been thus recorded.

Any rapid changes in speed are especially important in that they cause amplitude errors of such a nature that allowances cannot easily be made for them in the event that carriers are recorded. Recorders suitable for the recording of more than one carrier must have a frequency response corresponding to the extreme of the modulated carriers, and have a controlled time-base if amplitude errors are to be kept reasonably low. Even where the motor speed is constant, the mechanical problems of obtaining constant tape speed, for example, remain to be solved.

The recording must be made *after* the intelligence has been separated from the carriers unless the exact variations in time-base are taken into account. Recording the intelligence after separation from the carriers may be accomplished, in which case one step is saved over other methods, such as the ribbon-light valve, or the magnetic recorders. Additional conversions always contribute errors, and may reduce the time resolution.

High-pressure Drops Through Orifices*

By JOSEPH A. PERRY JR., Republic Flow Meters Co., Chicago, Ill.

MUCH information is available on low-pressure drops through orifices of a relatively large diameter ratio. The author undertook to investigate air flow with high-pressure drops through small orifices. In general this work pertains to orifice flow under conditions which are generally considered most undesirable in flow metering work.

Tests were made on orifices of 0.25 in. diameter and below. The greatest orifice to pipe diameter ratio, Beta, was 0.121 and the least was 0.076. This resulted in a velocity of approach factor of not more than 1.0001 or practically negligible. All tests were made on two-inch pipe. Pipe taps were used, i.e. one tap 2.5 pipe diameters upstream from orifice and the other 8 pipe diameters downstream from orifice. Whether pipe taps or vena contracta or flange taps were used would make very little difference in the results as long as small values of Beta are maintained.

The greatest upstream pressure used was 100 psia. Therefore the greatest pressure drop obtained was 85 psi. The air temperature varies from 80 to 100 degrees F. No medium other than air was tested.

To explain orifice flow it is perhaps best to use the nozzle as a basis of comparison because a great deal of work has been done on the study of the nozzle, and this work indicates that nozzle flow follows thermodynamic theory very closely. Flow of a gas through a nozzle may be stated as:

$$w = \frac{PA}{\sqrt{T}}\sqrt{\frac{2g}{R}\frac{n}{n-1}}\; r^{\frac{1}{n}}\sqrt{1-r^{\frac{n-1}{n}}} \qquad (1)$$

where: w = flow, pounds per second
P = pressure ahead of nozzle, psia.
T = temperature, degree F. absolute
g = gravity constant, 32.2
R = gas constant, 53.3 for air
n = ratio of specific heats, 1.4 for air
r = pressure ratio, ratio of downstream absolute pressure to upstream absolute pressure
A = nozzle throat area, sq. in.

From this question it is seen that a flow factor can be obtained from which flows at various upstream pressures and temperatures and through nozzles of various sizes may be correlated. And this factor is $w\sqrt{T}/PA$; this will be called Omega. Thus for nozzle flow

$$\Omega = \sqrt{\frac{2g}{R}\frac{n}{n-1}}\; r^{\frac{1}{n}}\sqrt{1-r^{\frac{n-1}{n}}} \qquad (2)$$

This may be seen graphically as the "nozzle" curve in Fig. 1. This equation is, of course, based on a zero velocity of approach.

A sharp-edged orifice will pass less fluid than a nozzle of the same size. To determine how much less, tests were made under the conditions previously described. For each test run values of Omega and the pressure ratio, r, were calculated. Their values were plotted and appear as the "orifice" curve of Fig. 1.

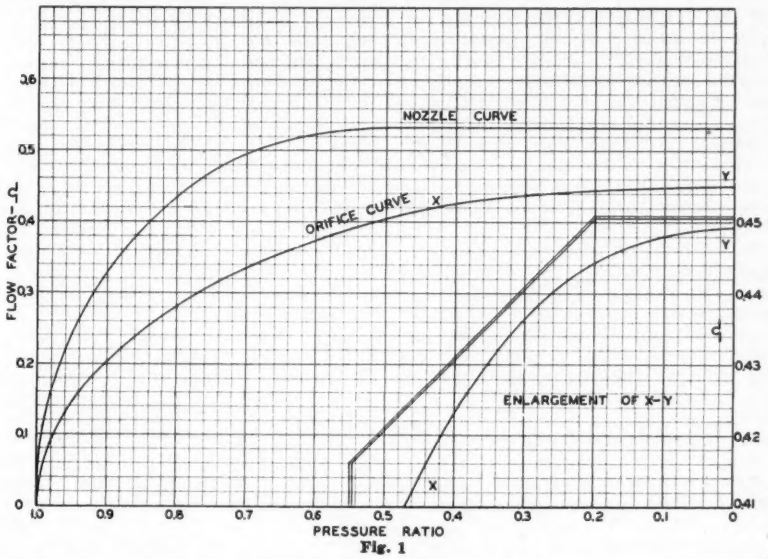


Fig. 1

From this curve it was found that sub-critical flow (from r = 1.0 to r = 0.53) could be expressed

$$w = 0.465\frac{PA}{\sqrt{T}}\sqrt{1-r^2} \qquad (3)$$

and critical flow (from r = 0.53 to r = 0) could be expressed

$$w = \frac{PA}{\sqrt{T}}(0.449 + 0.241r)\sqrt{1-r}$$

For convenience in making calculations pounds per second can be converted to cubic feet per minute by Q = 800w cu. ft./min. at standard density of 0.075 lbs./cu. ft.

So then working directly from Fig. 1,

$$w = \frac{PA}{\sqrt{T}}\Omega \quad \text{or} \quad Q = 800\frac{PA}{\sqrt{T}}\Omega$$

Two examples will be given which will show the method of using the chart and also serve to indicate the type of problem which can be covered.

Problem: Find the capacity of a compressor which was able to maintain 65 psig. on a 5/16-in. orifice in a 3-in. pipe discharging to atmosphere. Air temperature 90 degrees F. Barometric pressure 14.6 psia.

Solution: The diameter ratio is Beta = 0.3125/3.07 = 0.102. Thus the velocity of approach can be considered negligible. The pressure ratio is r = 14.6/(65 + 14.6) = 0.183. From the "orifice" curve Omega is found to be 0.444. Then the capacity is

$$Q = 800\frac{(79.6)\frac{\pi}{4}\left(\frac{5}{16}\right)^2}{460+90}(0.444) = 93 \frac{\text{cu. ft.}}{\text{min.}}$$

Problem: A process requires 20 cu. ft. per min. of air at 30 psig. The supply air is 80 psig. Determine the size of the breakdown orifice. Temperature and barometer same as above.

Solution:

$$r = \frac{30 + 14.6}{80 + 14.6} = 0.471$$

from the curve Omega = 0.41

then

$$A = \frac{Q\sqrt{T}}{800P\Omega} = \frac{20\sqrt{460+90}}{(800)(94.6)(0.41)} = 0.015 \text{ sq. in.}$$

The diameter is then 0.139 in. or approximately 9/64 in.

*This article is a condensation of a paper "Critical Flow through Sharp-Edged Orifices" which appeared in the *Transactions of the ASME* in October, 1949.

It Isn't *the* Heat - It's *the* Humidity*

By CHARLES A. MABEY, Upper Montclair, New Jersey

IT IS curious that as familiar a physical phenomenon as the presence of moisture in the atmosphere still lacks a generally satisfactory method of precise measurement. Observations of the moisture content of the air were certainly made by early Greek meteorologists along with the other characteristics as temperature and barometric pressure; yet, up to the present, improvements in means for measurement of humidity have been far outrun by the highly-developed apparatus for measuring atmospheric temperature and pressure. Perhaps there is little wonder, then, that in summer time we blame our discomfort rather vaguely on the humidity without knowing too well its relation to our sensation of heat or, in fact, its precise value.

This lack of satisfactory means of measurement has troubled meteorologists for many years, since they were probably the first, and undoubtedly, for a long time, the only people greatly interested in the measurement problem under other than laboratory conditions. In the last forty or fifty years, however, with the tremendous developments made in air conditioning, industrial drying and refrigeration, etc., humidity measurement has become a problem of far wider and more urgent interest. Yet, in spite of this progress and the expanding application to fields involving the manufacture of practically all of the necessities of modern living from bread to steel, in spite of the concentrated research inspired by this progress on the specific problem of humidity measurement, few, if any, important changes involving fundamental principles have yet been made in the classical methods of measurement for general industrial use. No disparagement of the many ingenious devices that have been developed employing chemical, electrical, and even optical principles is intended by this statement since these devices, it appears, may still be fairly considered as laboratory instruments and are not yet, at least, widely applicable to industrial uses. Today industry still depends almost exclusively on the three classical methods of measurement: The dew-point hygrometer, the psychrometer (or wet-bulb hygrometer), and the hygroscopic hygrometer.

Brief History of Hygrometry

To show the slow progress in this direction, it is interesting to review briefly some of the history of the art, especially as it pertains to these methods of measurement. The dew-point apparatus of J. F. Daniell, invented in 1819, has not been improved upon fundamentally though, of course, technical improvements in the manufacture of mercury-in-glass thermometers and in cooling media have extended its range and accuracy. Similarly, though to a somewhat less degree, the elementary psychrometer of Sir John Leslie dating back to about 1794-1795 is still a quite recognizable wet-and-dry bulb instrument. To be sure, the requirements for ventilation of the wet bulb were pointed out at a considerably later date, but the psychrometric formulae for humidity calculations based on wet-and-dry bulb readings were proposed by J. Ivory, an English scientist, in 1822 and still persist in use to the present day. In both these cases, apparatus of much earlier date could have been cited, such as the condensation apparatus of the Grand Duke Ferdinand II of Tuscany which dates back to 1653 and is, at least, an elementary dew-point device, or, the crude wet-bulb thermometer made by Baume in 1758.*

Regarding the hygroscopic type of humidity-measuring instrument, one can find in the scientific literature of about the middle of the Fifteenth Century the description of an hygrometer made by the Cardinal Nicolaus de Cusa consisting of a piece of cotton wool balanced against weights on a scale, the changing of moisture-content of the wool under the influence of changes in atmospheric humidity causing variations in the balance. This is more than vaguely reminiscent of an almost identical apparatus described in an English engineering publication of a few years back for control of humidity in a spinning room. Also, a similar hygrometer has been used, and perhaps still is, in this country, in which a small block of wood is substituted for the wool and the movements of the scale beam are used as a basis for control of lumber drying kilns. The most successful modern devices of this category employ the dimensional changes in hygroscopic substances with changing humidity, and one may find a very modern-looking counterpart to such instruments in an hygrometer made by de Saussure in 1783 using a human hair for the sensitive element.

Definitions

Naturally, it is not merely age that is the basis for the present dissatisfaction with these methods of measurement. The instrument-maker of today has applied all the latest techniques and mechanisms to the problem, but so far, at least, has been obliged to stick to the old methods with all their long-recognized limitations. Their difficulties are, basically, traced to the complicated nature of the measured quantity itself. In general, what is required as a basis for industrial control of drying of hygroscopic materials and of air conditioning for human comfort is the quantity, "percent relative humidity." This, by definition, is a ratio, expressed in percent, of the partial pressures, or the specific weights, of water vapor under the given conditions and at saturation at the same temperature, the total pressure of the given atmosphere being assumed constant. Obviously this involves determination of a relationship between at least two variables, that is, the dry-bulb temperature and the temperature of saturation (or dew-point), in the case of the dew-point hygrometer, and the dry-bulb temperature and the wet-bulb temperature (itself a rather complicated variable) in the case of the psychrometer. The measurement of the dry-bulb or atmospheric temperature presents no problem, but measurement of dew-point or wet-bulb temperature has difficulties and limitations. In the case of the hygroscopic hygrometer, its fundamental relationship to atmospheric humidity is only approximate, and since the properties of the natural substances on which its operation depends are largely uncontrollable, the present instrument does not presume to a high degree of perfection.

On the other hand, it is not to be assumed on the basis of these statements that modern instruments are devoid of all merit. The theoretical limitations, to be sure, have not been greatly altered but progress has been made in adapting these classical methods insofar as practical to modern indicating and recording instruments and, hence, to apparatus for automatic control. This article will attempt to indicate the present extent of this progress, showing the principles of design and the conditions of installation and maintenance from which the most satisfactory operation can be realized.

Dew-point Hygrometer

First of all, since the present discussion is primarily of instruments for industrial applications of automatic process control, the dew-point apparatus requires only brief mention. In contradistinction to laboratory methods of measuring humidity, of which there are far too many to be described here, industrial devices have been required to be as simple and fool-proof as possible for they must operate often under the most adverse conditions and maintenance of them is not always in expert hands. Moreover, in order to be adaptable to automatic recording and controlling, they must function continuously and automatically. Of the three methods available, therefore, the dew-point hygrometer is eliminated. In spite of the ingenious efforts of a number of inventors, no continuously recording device has yet achieved any

*Presented at a meeting of the Baltimore Chapter of the ISA in May, 1949, by the author who was, formerly, Director of Research of the Bristol Company, Waterbury, Conn.; now with Weston Electrical Instrument Corp., Newark, N. J.

*D. Dropkin, "Side Lights on the History of Psychrometry," *Mechanical Engineering*, May 1941, page 369.

great success. Nevertheless, it is simple, accurate and, theoretically, the soundest of the methods of measuring humidity, and, although it does require some skill in the operation of dew-point apparatus, it is still of great usefulness as a manually-operated instrument in some industrial processes as those, for example, requiring measurements of humidity under extreme conditions of pressure or temperature. It is also generally used as a reference standard.

The Psychrometer

The psychrometer, or wet-bulb hygrometer, is the most complicated of the present types of hygrometers. The modern instrument has been benefited, of course, by the improvements in instruments for measuring temperature. The theory of the wet-bulb has been thoroughly re-examined and brought up-to-date by Carrier[1], Lewis[2], Arnold [3], and Dropkin[4]. As a result, the old stationary wet-bulb hygrometer has been completely discredited. Even the familiar "sling" psychrometer, long used as a secondary standard in checking atmospheric conditions, is slowly being replaced by the Assmann type of psychrometer in which the thermometers are stationary, the bulbs are carefully shielded from radiation effects, and, instead of being whirled by hand, are provided with a suction fan for drawing the sampled air over the bulbs at an adequate velocity.

The psychrometer is only a special application of the thermometer and like all other applications involving measurements of temperature, the fundamental principle to be observed is that the registered reading should be the temperature at the point desired, uninfluenced by bodies or conditions in the vicinity at higher than dry-bulb temperatures. It is also important that reading does not lag too far behind either the condition being measured, or the reading of the dry-bulb.

Developments in recording thermometers have greatly assisted psychrometric measurements in industry. Liquid-filled (so-called Class I) distant recording systems are now available having sensitive bulbs of small size, 0.25 to 0.375 in. in diameter, which are rapid in response. Long capillary transmission systems are now possible with compensation for ambient temperature changes along the capillary as well as at the recorder case itself. Vapor-tension (Class II) and gas-filled (Class III) recording thermometers are also used but these require larger bulb sizes and are, hence, not to be preferred under conditions where the smaller Class I bulbs can be applied. Electrical resistance bulb thermometers using recording potentiometers lend themselves very well to wet-and-dry bulb measurements since they have the advantage of small bulb size, (in general, 0.25-in. diameter and about 1.5 in. long), also excellent responsiveness and the ability to make use of long wire transmission systems. To these thermometers are easily added all the wide variety of devices for automatic control, both electric and pneumatic, which have made them adaptable to the practical problems of industrial processes.

The Wet Bulb

The fixtures designed to apply the recording thermometer to industrial psychrometric measurements are many and vary considerably with the specific application, but certain general principles may be stated to apply to them all:

(a) Psychrometer bulbs should be as small as possible. Besides increasing the responsiveness, this simplifies the problem of supplying water to the wet-bulb and permits better distribution of the air-flow over the bulbs.

(b) Protection of wet-bulbs against corrosion is important. Even when distilled water is used for wetting, serious corrosion may occur, particularly when bulbs are of copper. The usual practice is to plate copper bulbs, preferably with chromium. Stainless alloy bulbs are frequently used, but because of the lower thermal conductivity of such materials, and also because of manufacturing difficulties, they are usually considered of doubtful advantage.

(c) Bulbs must be insulated from heat-transfer by conduction and radiation from other parts in their vicinity. In theory, the only admissible heat interchange is between the wetted sensitive bulb and the air sample flowing over it. Radiation may be minimized by enclosure of the bulbs with non-radiating shields, or by placing them in air tunnels the walls of which are made as far as possible non-radiating. Conduction can be an even more serious source of error, but it can also be practically eliminated if the sensitive bulb is attached first to a relatively long and thin extension, preferably of a material of lower heat conductivity, before it is attached to the holding bracket. In the case of the wet bulb, too, this non-sensitive "neck" should be covered as far as practicable by wicks, or other wetting means.

(d) Adequate air velocity for the wet bulb must be assured. For some time it has been known that this requirement varies with dry bulb temperature but a minimum velocity of about ten feet per second over the wet bulb is required for accurate psychrometric measurement. In general, however, for practical measurement over a range in which low values of percent relative humidity are encountered, a velocity of at least twice that value, or twenty feet per second, is preferable. Moreover, if electric fans or blowers are used, it is important that these should draw the air over the bulbs by suction rather than blow it lest heat generated by their motors should influence the temperature of the air sample. Naturally both wet and dry bulbs should be exposed to the same air stream.

Wetting Means for Wet Bulb

Adequate means for keeping the wet bulbs wet should be provided. The theoretical range of wet-bulb measurement is from far below the freezing point of water to its boiling point. Since between these limits there is a tremendous range of requirements for water to be evaporated, no one means of supply can be specified. For temperatures below freezing and up to about 120 F., cloth wicks are commonly used. These should be of a thin material, such as linen or rayon, and should cling snugly around the bulb and its non-sensitive extension with a "skirt" hanging from the bulb and dipping into a reservoir below. The wick may be fitted and sewed so as to cling to the bulb, but the sewing undoubtedly adds some resistance to capillary water flow unless it is carefully made. For this reason some users prefer to use wicks of thin, unsewed materials which, when wet, cling satisfactorily to the bulbs. Care must be taken, however, that such wicks do not become dislodged by the air movement. The exposed length of "skirt" may be important under some conditions since adequate opportunity must be allowed for the water carried to the wick to attain nearly the wet-bulb temperature before it reaches the bulb.

Where the wet-bulb temperature lies below the freezing point, the use of a reservoir to keep the wick supplied is impractical and under such conditions, it is necessary to add water manually at the required intervals to keep the bulb ice-covered.

The materials of which wicks can be made are, of course, many. In general, for best accuracy and quickest response, the thinnest possible material which will also supply the quantity of water demanded by the humidity condition being measured should be preferred. In practice, for temperatures below 120 F. and for bulbs 0.375 in. or less in diameter, a good quality handkerchief linen has been found most satisfactory. A cotton filler in the skirt aids materially in raising water to the bulb level. For other conditions a ribbed cotton balbriggan has been found generally satisfactory.

For temperatures above atmospheric, cloth wicks become increasingly impractical because of the difficulties of supplying by capillary action the larger quantities of water needed. Thus, porous ceramic tubes are commonly used to enclose the wet bulb. Water is introduced inside these tubes under just sufficient pressure so that it seeps through and is uniformly distributed over the outer surface without dripping. Tubes of various porosities are available, but exact specifications of these tubes for definite temperature ranges is exceedingly difficult since other factors of particular installation must be taken into account, chiefly, of course, the water demand. Because of manufacturing difficulties these tubes must necessarily be rather thick walled (usually at least 0.1875 in.) and fit the temperature bulb rather loosely, hence it should be realized that these are used with an appreciable sacrifice in accuracy and responsiveness. Experiments with thin wall ceramic tubes (of about 1 mm. thickness) have met with good success, but have the disadvantage of being quite fragile.

For extremely high temperature where the dry bulb temperature is well above the boiling point, above, say 250 F., metal sleeves over the wet bulb with many tiny drilled holes in them, and covered with a relatively thick wick of heavy cotton material, or even glass fabric, have been successfully used. The resulting readings are probably not very accurate, though such installations have given satisfactory results as a basis for control functions.

Wet-bulb Fixtures

A fixture designed for general application to humidity measurements under ordinary atmospheric conditions, based on the foregoing principles, is illustrated by Fig. 1. This embodies an air tunnel with blower of adequate capacity to draw air through at sufficient velocity. Small, Class I bulbs are used and are separated by a polished plate to eliminate radiation effects. The bulbs, as may be seen, have long thin extensions out to the holding brackets. A large supply of water, preferably distilled, may be kept in the inverted bottle fixture which after leveling automatically maintains the water level of the reservoir within the air tunnel. Maintenance of this requires only that the water supply is replenished as needed and that the wick be periodically changed as dirt accumulates from the air.

In the wide variety of other fixtures for installation of bulbs in ducts, kilns, or ovens, or other locations, it is not always possible for the instrument manufacturer to take care of all the requirements for satisfactory measurement in his designs. The user must, therefore, assure himself that psychrometer bulbs have adequate ventilation, are properly located with due regard for radiation and conduction and that adequate water supply is assured.

Maintenance of the Psychrometer

Care in maintaining the wet bulb in operation is essential to continued accuracy of its measurements. Distilled water is desirable but not necessary for the wet-bulb, but where tap-water is used, obviously the dissolved and suspended constituents eventually accumulate to impede and stop capillary action. Presence of oil or large amounts of dissolved salts can so affect vapor pressure that serious inaccuracies can result. Hence, frequent periodic inspection of bulbs, water supply and wicks, or porous sleeves must be provided.

Wicks can usually be cleaned by washing, or, if in an oily condition, boiling in a mildly caustic solution is satisfactory. Ceramic sleeves also become clogged with solid residue from the evaporated water, since ordinary tap water is often used. Cleaning of these may be accomplished by immersing them in strong acid solution.

Psychrometer Readings

A general characteristic of psychrometers is that the measuring instrument registers finally two temperatures, that of the dry bulb, and that of the wet bulb. To convert these readings to values of percent relative humidity, it is necessary for the user to refer to tables or curves of such data. Of course, these temperatures may be easily recorded, or either one or both may be used as a basis for automatic control of air-conditioning by standard apparatus for the purpose. However, the necessity for the manual translation of the readings to the conventional humidity units is frequently a disadvantage. The automatic combination of them to effect a direct registration would be of obvious usefulness, but unfortunately, to date at least, has not been very successfully done. The curvature and dissymmetry of the basic psychrometric curves have proven a serious obstacle to such translating devices. To be sure, several instruments having this feature

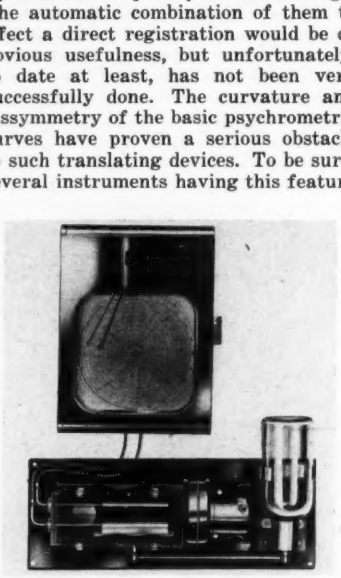


Fig. 1

have been available on the market but they are complicated, expensive, and of doubtful accuracy except over limited temperature ranges and, have, therefore, not been widely accepted.

The Hygroscopic Hygrometer

The only direct-reading hygrometer, registering, that is, percent relative humidity values directly, is the hygroscopic type, the third of the classical methods of measurement. From its wide application as a household indicator of humidity (the so-called "hygroscope"), or as "hygrostat" controller for small air conditioning installations, this type has become by far the best known to the layman. In general, it may be said that its outstanding virtues are its simplicity and its ability to be calibrated directly in terms of percent relative humidity; its vice lies in the somewhat erratic and uncontrollable properties of all hygroscopic materials. Practically all commercial instruments of this type use the property of change in physical dimensions of cellular organic materials with changes in moisture content; but moisture content depends on the relative humidity of the surrounding atmosphere and, fortunately, only to a considerably smaller extent on the temperature of that atmosphere. Therefore, relative humidity and changes in elements are directly related one to another. It is a thoroughly empirical instrument; it does not bear close theoretical examination. It is well known that the hygroscopic property of materials depends on the history of any particular sample, that the equilibrium condition may depend on the direction from which the condition is reached, producing an hysteresis effect; that exposure to sudden or extreme conditions of humidity or temperature may produce erratic behavior and even permanent changes in the material; and that while the equilibrium between %R. H. and dimensional changes is only relatively slightly affected by temperature, this temperature effect cannot be completely ignored.

Many types of these hygrometers employ human or animal hair, or gut or even paper held in tension as humidity sensitive elements. These make satisfactorily sensitive detectors of relative humidity change but have a tendency to stretch under the mechanical tension particularly at high relative humidity values requiring frequent checking and resetting.

The "Humidigraph" Hygrometer

A very successful element is available employing a thin membrane of wood fibres lightly but firmly cemented to an impervious plastic strip and wound into a helix which operates in a manner analagous to the familiar bimetallic temperature spring. This has been found to have considerable mechanical torque under the influence of relative humidity changes and is not easily stretched by mechanical strains. It is, therefore, more permanent in calibration and, further, quite adaptable to devices for automatic control. Suitable choice of material and treatment has practically eliminated hysteresis effects and also effects of aging. Moreover response can practically be made didectly proportional to the percent relative humidity.

Tests have shown that these hygrometers generally require frequent recalibration and readjustment if exposed to widely varying temperature and humidity, as, for example, if used for measurement of outdoor atmospheric conditions. Particularly damaging is exposure to high values of percent relative humidity near saturation from which recovery is very slow if at all. However, fortunately, in most industrial applications humidity measurement and control is made within relatively small ranges and hence this type of instrument has proved a very useful tool. Under such conditions, accuracy of the order of plus or minus 1 to 2 percent relative humidity are feasible, and calibration of instruments can be maintained for long periods. In refrigerated atmospheres, where the use of the psychrometer is impracticable, the hygroscopic instrument has proved a preferable alternative for automatic recording and control.

In use, the hygroscopic hygrometer is subject to a few simple rules. It is usually a self-contained recorder or indicator, with or without controlling features added, that is, the sensitive element has to be mounted close enough to the recording or indicator mech-

anism to allow mechanical transmission of motion. Extensions for insertion of the sensitive element into a duct system, with recorder mounted externally, are feasible but the limit of extension is not much more than about eighteen inches. Secondary transmission systems of standard pneumatic or electric type are also available for recording at greater distances or for amplification of the power available. Naturally some air movement over the sensitive element is essential in order that a sample representative of the atmosphere being measured is brought in contact. In general, it is desirable to actually provide forced ventilation and small fans or aspirators are then provided.

Checking of Hygrometer

Periodic checking against a standard psychrometer or dew point apparatus

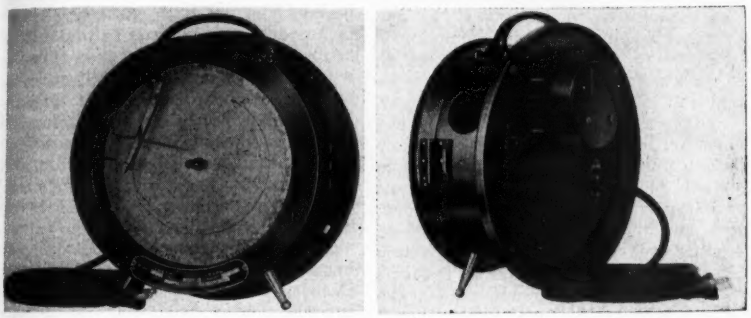


Fig. 2

is recommended and particularly after installation since conditions encountered during shipment of the hygrometer frequently cause zero-shifting to occur. (By zero-shifting it should not be implied that such instruments are or should be checked at 0 percent relative humidity. Ordinarily the standard point of reference, or "zero," is taken as 50 percent relative humidity). If the instrument is intended for sub-freezing measurements, it is essential that the check be made under conditions of use since no factory calibrating can be maintained through the period of packing and shipping. Similarly, if used in the range of temperature above atmospheric this check of calibration is imperative.

Fig. 2 shows a hygroscopic type of hygrometer widely used portably for checking air-conditioning in the comfort range. Both the temperature element and the wood fibre humidity elements are mounted inside the instrument case and a fan on the back of the case draws air over the sensitive elements.

New Developments

Before concluding, a word should be added to mention briefly new hygrometer devices which, at least, for special industrial applications, show considerable promise. An element has been devised which measures the change in resistance due to absorbed moisture on a film of treated plastic material. Another, similar to this and analogous to the old dew-point hygrometer, maintains a film of a saturated deliquescent salt in temperature equilibrium with the atmosphere around it by passing an electric current through the solution thus automatically adjusting the heating effect by resistance change. A third promising development is in the measurement of absorption of infrared radiation as a function of quantity of water vapor present in a gas-sample. Each of these has its own particular merit but not enough is known at this writing to estimate their importance in the general field of industrial measurements over the methods already described.

Conclusion

In general, however, we have been primarily concerned with the three so-called "classical" methods of measuring atmospheric humidity as applied to modern devices for automatic indicating, recording and controlling. In general, the large fields of application for these can be roughly classified as: (a) Air conditioning for human comfort, health efficiency; (b) drying and control of physical properties of materials; (c) control of chemical reactions; (d) control of biological processes (including preservation of food) and (e) analysis of compressed gas. Within these fields is represented a wide range of temperature and humidity conditions. The preferred instruments available for measurement and control for any particular field can not be definitely assigned without taking into account many specific factors involved. However, from the text of this article it was intended to imply that for the upper temperature ranges above, say, 150 F., the psychrometer alone is available and with special wetting devices as those described provides a moderately accurate means which can be suited to the demands of automatic control. The hygroscopic hygrometer, particularly the wood fiber element described can be used up to about 150 F. but requires more frequent checking when used in the extreme region. At atmospheric temperatures above freezing point, either method is available and the selection should be made on the basis of the usefulness in the particular application of a wet and dry bulb temperature measurement as against a direct reading in terms of percent relative humidity. The controlled system for humidification or dehumidification in any installation may presumably be adapted to either type of measurement through electric or pneumatic intermediate devices. Below freezing, both the hygroscopic hygrometer and the psychrometer have been used and have been found reasonably reliable if properly installed, checked and maintained.

From this summary of the instruments available for the measurement of relative humidity in industry, the defects and deficiencies of available instruments are all too apparent. Undoubtedly many industries have been hampered by a lack of a neat, universal method of measurement which could be applied with confidence to any given set of conditions whence consistently reliable and accurate results could be assured as a basis for automatic process control. It is, admittedly, unfortunate that this is the situation—unfortunate, but not hopeless. It is true that except, perhaps, for the range of comfort conditions, accuracy in terms of any absolute standards of humidity measurement is practically unattainable, but it is true that in industrial practice, absolute accuracy is little more than an academic ideal. Sir Napier Shaw, the eminent English meteorologist, has said, "considering that the atmosphere is always in turbulent motion, and the process of mixing is always going on, it is really doubtful whether the actual humidity of a small portion of the atmosphere is a physical quantity to be measured by any instrument freely exposed to the passing air." This criticism certainly applies to industrial problems of measurement in large volumes of air in which, in general, uniformity in moisture content does not exist and, nevertheless, the measurement of humidity of a small sample is expected to be representative of the conditions in the whole volume. The requirements of industrial practice fortunately have not insisted on this absolute accuracy but rather the practical ability of the instrument to duplicate consistently its registrations under given measured conditions. Another feature of industrial control instruments which places these devices under the most favorable conditions is the fact that they are mainly used to detect variations from a fixed control point over a relatively small range. As we have seen in the foregoing descriptions, the conventional methods of measurement do not perform satisfactorily under widely varying conditions, hence this situation is much more fortunate than, say, the problem of meteorological measurements of humidity in which widely varying conditions of both temperature and humidity are to be measured. Of course, as this article has tried to point out, in order to realize any of the virtues of these instruments, within their range of usefulness they must be intelligently applied and conscientiously maintained. In any review of existing industrial hygrometric instruments, these requirements should stand out as the sine qua

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High Vacuum Evaporated Optical Coatings

By ROBERT E. FRAZER, Chief Engineer, Pacific Universal Products Corp., Pasadena, Calif.

IN THE past twenty years high vacuum practice has enjoyed a growth paralleled only by the science of electronics and, understandably so, since the whole art of the electron tube depends for its success on the creation of high vacuum. This creation of high vacuum is almost daily invading new fields where short months ago the mention of the name would have brought only raised eyebrows. No treatise can hope to cover the subject completely. For that reason this article will confine its comments to the use of high vacuum as a medium (or more precisely a lack of medium) for the evaporation of stable metals and compounds.

Researchers early recognized that many of their problems would be more readily solved if they could boil metals and compounds and subsequently condense the vapors without the physical and chemical handicap of the atmosphere, especially oxygen. To understand the history of high vacuum evaporation, we must trace the growth of high vacuum pumping as it progressed from the humble mercury fall pumps of the Edison era through the Holweck and Langmuir pumps to the high-speed oil diffusion pumps of today.

At this point one is entitled to ask, "Why this much ado about nothing?" "Why not evaporate our metals in an inert atmosphere to avoid oxidation?" The not so obvious answer is that a molecule of metal is able to "boil off" of the hot parent mass by acquiring sufficient speed or thermal velocity to carry it away. It will keep traveling at its original velocity only so long as it suffers no collisions to rob it of its speed or temperature. Each collision, for example with air molecules, removes a portion of the original heat of the evaporated molecule, which soon loses its velocity and reverts to a slow-moving particle, incapable of reaching its target. The main purposes of carrying on this evaporation in a region free of foreign molecules is to decrease the risk of collision of the evaporated molecule, and thereby increase its useful range from a few thousandths of a millimeter to several meters. Such an increase in mean free path corresponds to a decrease from the normal atmospheric pressure of 760 mm. to the low value of 1/100,000ths of a millimeter, or about 10 billionths of atmospheric pressure. At this pressure, risks of collision between molecules are about as great as risks of collision between a fly bound from Los Angeles to New York and another flying from New York to Los Angeles over the most devious routes.

The problem of reaching pressures of about 1/1,000ths of a millimeter was solved by mechanical pumps of refined design, but to better the limit of such pumps by a factor of 100 to 100,000 called for the strategic use of other molecules. Probing in the directions suggested by Gaede in 1913, Langmuir is credited with first developing a so-called diffusion pump employing a curtain of high-speed mercury molecules traveling in such a direction that diffusion through it is essentially in one direction when a mechanical pump is arranged to remove the molecules as they accumulate. Such a pump is capable of reducing the pressure in a closed vessel by a factor of 100, and when arranged in series with another similar pump, the limiting pressure is further reduced. Pumps of this type were immediately adapted for laboratory use in spite of the necessity of using a cold trap to remove mercury vapor from adjacent vessels. Systems using mercury pumps and cold traps were adequate for evacuating small tight vessels of glass, but, being made of glass, their utility was limited. Steel pumps of greatly increased speed soon appeared, but their speed was largely sacrificed in the traps necessary to remove the mercury vapor.

Kenneth Hickman, working in the laboratories of the Eastman Kodak Company, is credited with the refinements in pump design and the development of the special oils which are now teamed up in giant pumps 20 and 30 inches in diameter. Pumps of this size are capable of handling such a volume of gas throughout the range below 1/1000th of a millimeter that they are being used to power low pressure wind tunnels.

While the old falling-mercury pumps contributed to the birth of the incandescent lamp and the simplest vacuum tubes, it remained for the early mercury-diffusion pumps to open the way for their commercial production. This same period saw the introduction of vacuum discharge tubes of the neon sign variety. Likewise, complex electron tubes had their beginnings with the early mercury diffusion pump.

One of the first applications of high vacuum evaporation was in the field of optics for the production of front surface mirrors. A milestone in the art of metal evaporation was the aluminizing of the 100-inch mirror at Mount Wilson. It is worth noting in this connection that the then used technique of boiling the aluminum off of electrically heated open coils of tungsten has persisted as the most widely used method today. Variations of this technique have met with acceptance. Early among these was the idea that a film of chromium with its greater affinity for glass could be evaporated to be subsequently coated over with aluminum to yield a highly reflecting surface. Where surfaces are of questionable cleanliness, or where it is desirable to have a permanent under layer of hard material which will offer a degree of reflection should the aluminum surface be destroyed, the pre-coating with chromium may be justified.

Today, little of the advantage remains because with refined cleaning techniques, aluminum is so well secured to its glass support that even stripping with cellulose tape fails to destroy the bond. Contrary to some belief, an aluminum film directly on glass offers the same resistance to scratching as does an aluminum film over chromium. The argument in favor of the aluminum over chromium stems from the fact that in such a case, the top layer of aluminum may be ruptured without penetrating the harder undercoat of chromium. Such an abrasion may not be apparent by transmitted light, but the damage has been done nevertheless, since a scratch is detrimental not through loss of light from the region destroyed but through stray light scattered into the image from the boundaries of the defect.

What is really wanted then is a mirror surface which will resist normal handling and corrosive atmosphere. Such chemical stability is offered by the precious metals, but only one of them, rhodium, possesses sufficient hardness to commend it from the handling standpoint. Mirrors of rhodium are currently being produced by two methods:

1. Direct sublimation from a rhodium ribbon heated in vacuum just below its melting point.

2. Evaporation of a conducting film to serve as a base for a subsequently electroplated film of rhodium.

Both of these methods yield mirrors of excellent physical and chemical properties, but both are also disappointing optically with a reflectivity of about 70 percent.

Of all the metals, aluminum offers the best reflectivity, and if some means could be found to protect its surface without sacrifice of its 90 percent reflectivity, on ideal mirror should result. Two techniques were evolved:

The first hinged about the use of quartz as the protective coat. This was a logical choice because of the near indestructibility of quartz, but the permanence of silica starts with a near permanent respect for the solid state. It is well nigh impossible to evaporate consistently. This difficulty can be sur-

*Presented at the second annual convention of the Western Amateur Astronomers, August 14-16, 1950, Leland Stanford University, Palo Alto, Calif.

mounted by effecting a more efficient transfer of heat from the tungsten to the quartz, but still the results are unpredictable, a factor when irreplaceable optical elements may be damaged by spattered particles of hot material. In spite of their drawbacks, quartz films offer protection without the need of heating the glass. This fact justifies their use on certain types of work.

A second technique was an outgrowth of methods used so successfully for the low reflectance filming of optics with a one-fourth wavelength coat of magnesium fluoride. In this process the aluminum is evaporated onto the glass in the customary manner from a tungsten filament. The glass is then heated to about 400 F., and the magnesium fluoride evaporated from a molybdenum boat or crucible. The fluoride coat is limited to less than one-fourth wavelength of violet light to prevent reflections in the fluoride layer from imparting an interference color to the film. Where such an interference color can be tolerated or may be advantageous, thicker protective coatings of magnesium fluoride have been used. As might be surmised from the low reflectance properties of fluoride films on glass, a related phenomenon is responsible for the slightly higher reflectivity of a first surface mirror overcoated with a film of fluoride one-half wavelength thick.

The slightly improved reflectivity of the surface for wavelengths twice the thickness of the film may be advantageous especially where the mirror is designed for use over a specific region of the spectrum. Little merit has been found for such coatings in visual instruments.

These fluoride coatings yield good mirrors, but the work must be heated as indicated to develop the maximum surface hardness, and to render the fluoride film insoluble in water. Heating massive optics to temperatures of 400 F. is a hazardous operation even with pyrex, and without heating, the protection would not be permanent due to the solubility of the fluoride in condensed moisture.

It would seem that the ideal protective coating should combine the permanent hardness of quartz with the ease of evaporation of fluoride without the latter's requirement for heating the work. Such a material was evolved and used successfully by the Germans during the War. Mirrors are now produced commercially by this process with only slight refinements in the techniques originated abroad. Basically, the routine is the same as used for fluoride overcoating except that the work need not be heated. The aluminum is evaporated in the time honored way from a tungsten filament. The evaporation is arrested at the required transmission (in the case of a partial mirror) or at opacity in the case of a total reflector.

Immediately thereafter, current is passed through a molybdenum boat containing a small but known amount of the overcoating material. At a temperature of about 1800 C. the material undergoes a chemical change and evaporates as silicon monoxide condensing on the aluminum as that compound. Prior to evaporation, the material is essentially a mixture of silicon dioxide (quartz) and silicon metal in the proper proportion to yield silicon monoxide after combination. Although the actual sequence of this reaction is not completely understood, it is established by Haas in a recent paper that the evaporated film is largely silicon monoxide until the work is removed from the vacuum. As soon as oxygen is available, the outermost layer of silicon monoxide starts to oxidize to the more stable silicon dioxide, and this continues in time to some depth in the film. The speed of this oxidation, as well as the total depth oxidized, can be increased by heating in air at about 250 C. Even prolonged heating does not seem to completely oxidize the surface, but this is not a serious concern, since silicon monoxide itself approaches the hardness of quartz. An aluminum mirror overcoated with silicon monoxide to a depth less than one-fourth wavelength and subsequently heat treated as indicated, is capable of resisting abrasion 1400 times as long as an unprotected fresh aluminum mirror.

Mirrors of this type offer the best answer to date for the optician seeking something more permanent than bare aluminum. It should be again emphasized that large masses of glass will develop excellent surface hardness in air at room temperature, while small pieces, such as diagonals, can be heat-treated to achieve maximum abrasion resistance.

High vacuum evaporation is useful to the astronomer and optician for purposes other than the production of mirrors. The last war served to emphasize one of these uses, and for that reason a few words on low reflectance coatings are in order.

Each glass air surface of an optical instrument reflects from 4 to 7 percent of the light incident upon it. In complicated optical devices such as the periscope the sum total of these losses may rob the observer of as much as 60 percent of the luminosity of the image, and this loss during dawn and dusk hours may well mean failure to distinguish an enemy target. As if the loss of light were not enough the light lost by reflection is redirected by adjacent surfaces and a good portion ultimately arrives at the observer not as a useful image, but as out of focus images and over-all scattered light to blanket the already dim image with a contrast destroying haze.

This same phenomena occurs in nearly every visual and photographic optical system to some degree, and to that same degree the performance of such instruments can be improved by the low reflectance coating of their surfaces.

Much the same transition that marked the development of improved mirrors is now a matter of history in the case of the high vacuum coating of lenses.

The outgrowth of all the groping for the ideal lens coating material is that the industry has largely settled on the use of magnesium fluoride as the best compromise between efficiency, hardness and ease of operation. In the course of this groping many materials of high optical efficiency were discarded because they were impossible to apply in a film sufficiently hard to resist the abuse of service conditions. Other techniques for chemically attacking the glass were not applicable to all glass types equally, and still other methods of mechanically applying a thin liquid film to the surface and subsequently hardening the surface were found to be difficult to control except on the surfaces of larger glass pieces. All factors considered, magnesium fluoride is still the best material for lens coating.

The complex wide field eyepieces used on certain binoculars, military instruments and some finder telescopes may have as many as eight glass-air surfaces. A fair average for losses at the surfaces of high index glass used in such eyepieces is about 5 percent of the incident light. Since 95 percent of the initial light remains after passing one surface, the amount remaining after 'n' passages is 0.95^{n-1} or about 66 percent. Of this, 34 percent lose light. All but some 8 percent can be reclaimed by coating, thereby restoring the transmission of the system to about 92 percent. As previously indicated, such a coated system is not only more luminous and contrasty, but is remarkably free of ghost images and flare.

It is true that astronomical eyepieces of the Ramsden, Kellner and Orthoscopic types do not suffer the light loss of the other types but it is equally true that they are not immune to ghost images and flare.

Although eyepieces are being coated as a routine operation in most shops, the treatment of objectives of large diameter involves some interesting variations in technique. It is well known that the thicknesses of a film must be accurately one-fourth wavelength to satisfy the conditions for maximum efficiency for that wavelength. It is also well established that the intensity of a beam of molecules projected in a vacuum from a small central source toward an adjacent "flattish" surface suffers increased attenuation in reaching the edges of the receiving surface as the distance and angle of incidence increase at this edge. This attenuation can be minimized by placing the source at a greater distance but equipment size places a strict limit on this approach. A logical solution is to arrange multiple sources on some radius which will result in more uniform radiation over the surface in question. Better yet, the work can be rotated over a single source so decentered as to produce a symmetrical density of molecular radiation over the rotating surface.

A third method consists of interposing a rotating baffle between the lens and the axially located source. The shape of such a baffle can be varied to channel the radiation in any desired

Continued on page 322

A Novel Measuring *and* Proportioning Method

By JOSEPH C. FROMMER, Electronic Consultant, Cincinnati, Ohio.

ELECTRONIC measurement of a multiplicity of industrial data can be reduced to the measurement of photocurrent, ionization current, or the like. The usual practice is to send such currents through a load resistor and measure the voltage developed across its terminals. Such measurement depends on the sensitivity of the phototube or other sensing device used and on the ohmage of the load resistor. If either of these values changes, the reading will be affected by a proportional error. To avoid these errors, occasional recalibration is necessary. The more frequently recalibration is effected, the more reliable the measurement is. The ideal would be to have recalibration done automatically at short intervals and make the instrument read the proportion between the signals coming from the magnitude being measured and the magnitude serving as a standard. Such arrangement yields full accuracy even with phototubes or other sensing elements having a steady drift in their sensitivity.

Automatic continuous calibration and ratio reading can be achieved by the principle* described as follows:

The sensing element (e.g. phototube) is exposed simultaneously to both the magnitude to be measured and to the calibrating magnitude. But whereas the first of these is left to act continuously, the action of the second is periodically interrupted. The current (photocurrent) obtained corresponds to the magnitude to be measured alone in one period of the cycle, and to the *sum* of the magnitude to be measured and the standard magnitude in the other period of the cycle. Fig. 1 shows schematically how phototube P is exposed to the light transmitted through sampling cell C1 continuously, and to the light transmitted through standardizing cell C2 intermittently, the interruption being performed by the rotating disk D having opaque and transparent segments. The proportion between the photocurrent flowing in one period and the *increase* of photocurrent during the other period is the measured magnitude expressed in terms of the calibrating magnitude: the light transmitted through the medium in cell C1 in terms of the light transmitted through the medium in cell C2.

To obtain this proportion, advantage is taken of two facts: (1) that the difference of two logarithms is the logarithm of the proportion of the two arguments, and (2) that circuit elements are available the voltage across which is a logarithmic function of the current flowing through them. An important group of such circuit elements is the grid-to-cathode path of vacuum tubes. If the grid is kept negative with respect to the cathode, then the grid current is negligible for practical purposes. But in the absence of grid bias, electrons are emitted from the cathode to the grid. The value of this grid current depends on the voltage between grid and cathode and can be expressed by the formula:

$$I = I_0 e^{V/U} \qquad (1)$$

where e is the base of natural logarithms, V is the voltage between grid and cathode, and I_0 and U are constants depending on the vacuum tube being used. This equation is based on the distribution of energy between electrons leaving thermionic emitters and is valid for all vacuum tubes irrespective of type or make.

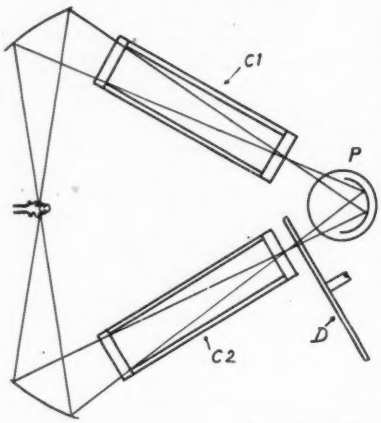

Fig. 1. Optics of a Colorimeter. Light from lamp is directed to phototube P through liquid under test in cell C1 and through standard liquid in cell C2. Light through C2 is periodically interrupted by disk D.

If the cathode of a phototube is connected to the grid of a vacuum tube and this interconnection point is kept insulated from all other parts of the circuit, then the photocurrent flows between cathode and grid of the vacuum tube and the voltage on the grid assumes a value governed by Eq. (1). To express the grid voltage as a function of grid current, this equation can be written:

$$V = U \log I/I_0 = U \log I - U \log I_0 \qquad (2)$$

Thus, if in the arrangement of Fig. 1 the photocurrent is I_1 during the period in which the phototube is illuminated through the cell C1 alone, and $(I_1 + I_2)$ during the period in which it is illuminated through both cells C1 and C2, then the voltage on the grid assumes

$$V_1 = U \log I_1 - U \log I_0 \qquad (3)$$

Continued on page 321

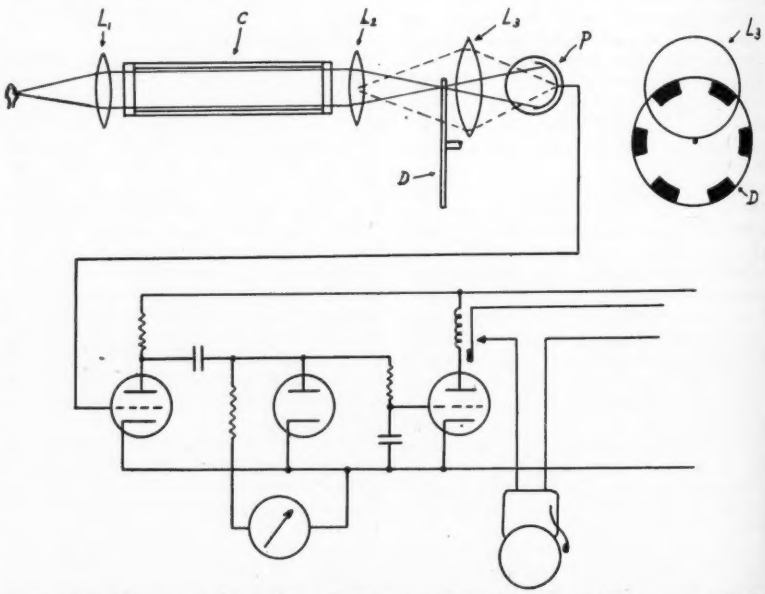

Fig. 2. Detection of Cloudiness. Rays focused through liquid under test in cell C are periodically interrupted by disk D. Rays scattered by cloudiness and falling outside the path of dark portions on disk D are uninterrupted. Both interrupted and uninterrupted rays are gathered on phototube P. Photocurrent of P flows between grid and cathode of amplifier tube, causing on grid an alternating voltage depending on the proportion between interrupted and uninterrupted illumination. This alternating voltage is amplified, rectified, indicated and used to actuate relay and sound alarm if cloudiness exceeds a preset limit.

*U. S. Patent No. 2,517,554.

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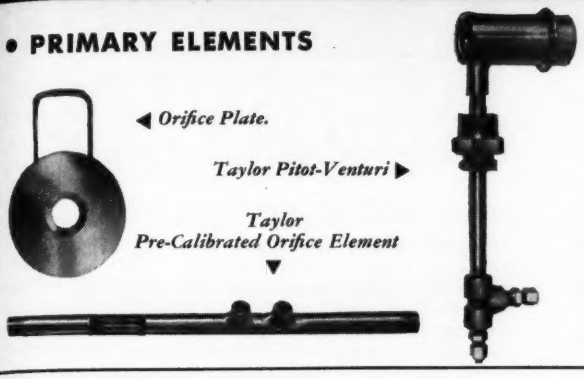

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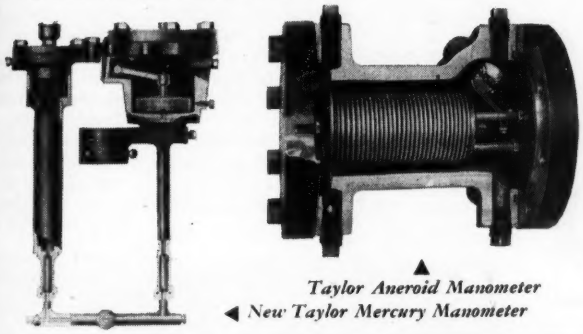

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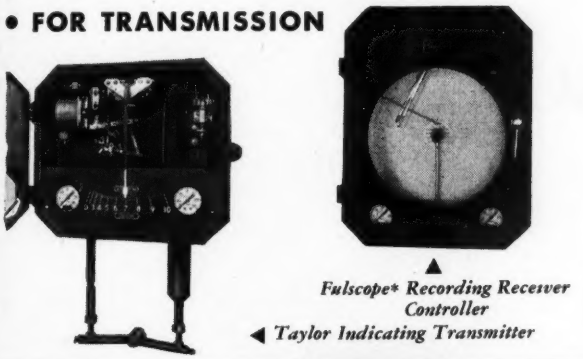

▲ *Fulscope* Recording Receiver Controller*

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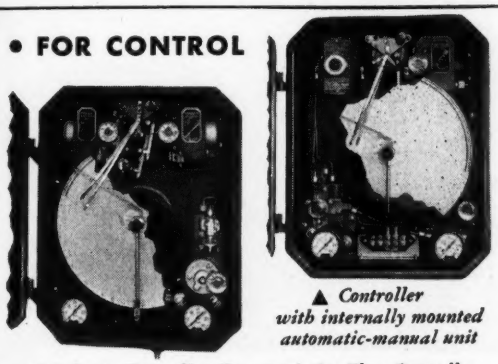

▲ *Controller with internally mounted automatic-manual unit*

▲ *Fulscope Recording Pneumatic-Set Flow Controller*

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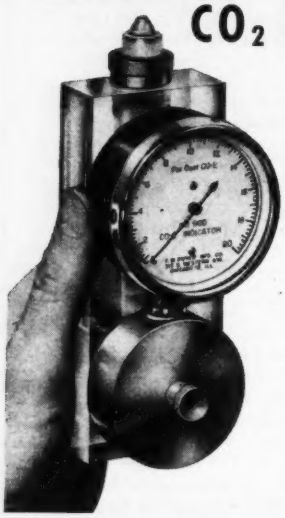

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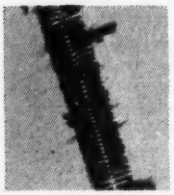

END THIS!

This enlarged photo shows carbon and oil impurities clogged in old-style unprotected filament after chemical or exhaust gas analysis. Result is changed resistance, inaccurate readings, after short use.

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INSTRUMENTS ON THE MARCH

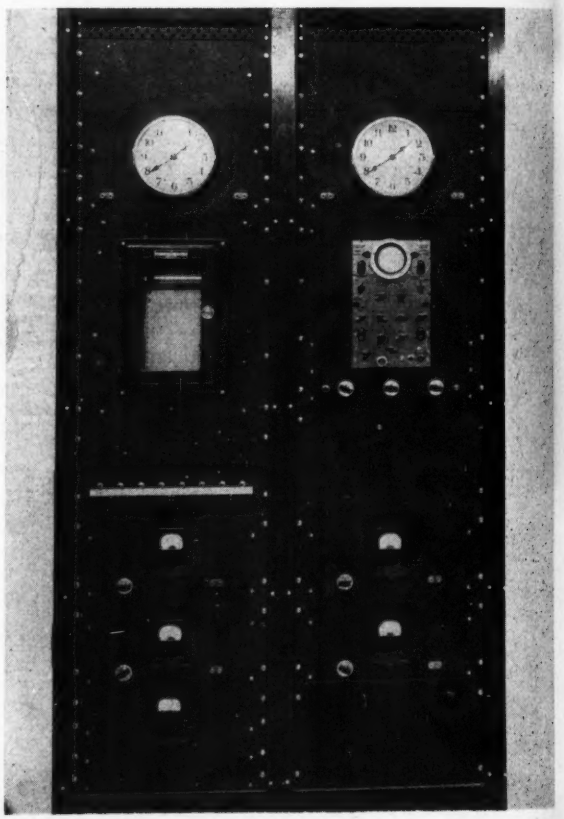
Improved Spark Chronograph and Chronoscope

Refinement of the National Bureau of Standards' system for monitoring the precision time-keeping of a group of standard crystal clocks consists of an improved spark chronograph and chronoscope which together record time differences as small as 20 millionths of a second. The new development may be easily applied to checking stability of oscillators and frequency dividers and rating clocks and chronometers over long periods of time. The method is now being applied, in principle, by watchmakers for the rapid adjustments of watches and clocks.

The spark chronograph records time differences of two clocks to one milli-second by linearily sweeping a spark discharge point across the waxed paper strip of a specially designed recorder. The chronoscope uses the visual characteristics of the cathode-ray tube to increase the resolution of the chronograph to 0.02 milli-second. Together these instruments constitute a reference clock with which all other crystal clocks comprising the primary standard may be intercompared.

The improved spark chronograph includes a single-turn

NBS Technical Report 1449.



Improved chronograph and chronoscope recently developed by the NBS shown installed in conjunction with two crystal clocks. Rack at left contains equipment essential for operation of one clock and the chronograph. Rack at right contains pulsing circuits for chronoscope and duplicate dividing and control circuits which may be connected to chronograph in event of failure of normal source.

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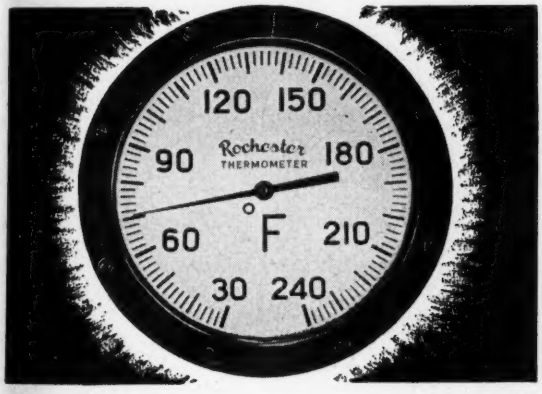

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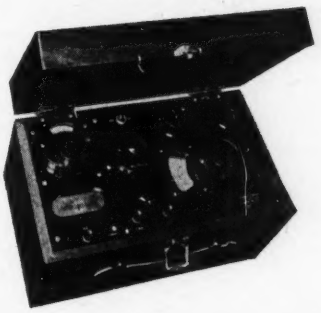
Described in Bulletin 100



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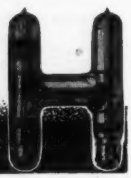

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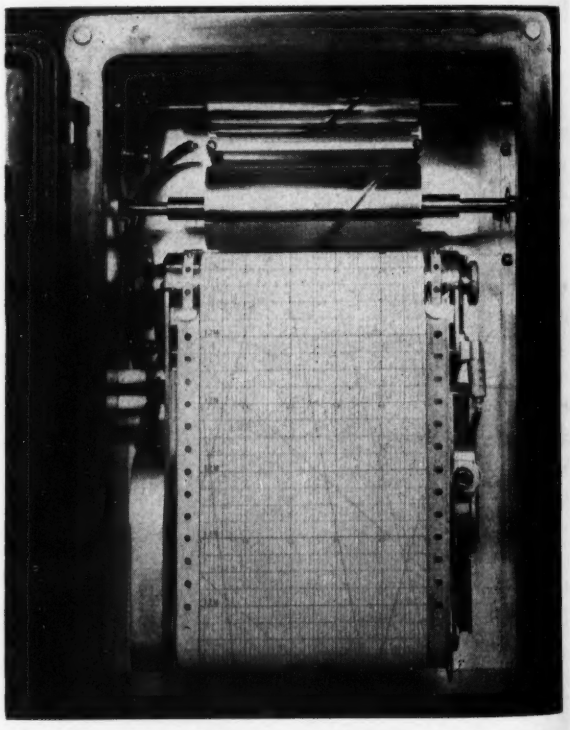
helix wound on a rotating drum driven by a synchronous motor. Beneath the drum is an insulated knife edge over which a strip of waxed paper slowly passes. A high-voltage pulse causes a spark to jump from the knife edge to the nearest point of the helix, perforating the paper, melting the wax, and thus leaving a permanent record. Should the motor driving the drum be supplied by subfrequencies from a standard oscillator while the high-voltage pulse is controlled by another crystal clock, a recorded picture of the relative rates is readily obtained. If the drum-control frequency is equal to the spark-control frequency, each time a spark occurs the rotating drum turns through an angle which is an exact multiple of 360 deg. Thus, the same point on the helix will be opposite the knife edge, and the record on the waxed paper will be a straight line running vertically up the chart. However, should there be a difference in frequencies, the drum will rotate through a greater or smaller angle, causing a different point on the helix to be nearest the knife edge at the time of the spark. As a result, the record will slope to the right if the clock controlling the spark is running faster, or to the left if the clock is running slower. The difference in rates may be evaluated by measuring the amount of displacement over a given period. If the spark generating equipment is switched, in turn, to each of several clocks, the chronograph provides a convenient method of intercomparing and recording their operation. A motor-driven switching unit connects each clock to the spark generator every 15 minutes and push buttons permit manual checking at any time.

The rotating drum is made of stainless steel; a helical groove is cut into its surface, and a steel spline is soldered into this groove. The synchronous motor drives the drum at ten revolutions per second, causing the helix to cover a time interval of 0.1 second per sweep. To indicate in which tenth of a second the helix is turning, a smaller drum is mounted above the major one and geared down to rotate at a speed one-tenth as great, and passes over another knife edge divided into ten parts. A switch enables application of



Indelible graphic record of the spark chronograph will indicate time differences of one millisecond between two crystal-controlled clocks. Two cylinders at top of casing are the small one-second drum (above) and the larger 1/10-second drum (below). Knife edge below one-second drum visually indicates in which 1/10-second the larger drum is recording. Knife edge for 1/10-second drum is supported beneath it by insulating rods. At discharge a spark from knife edge strikes helix and pierces waxed paper recording strip. Switch at the left changes the pulse voltages from one drum to the other.

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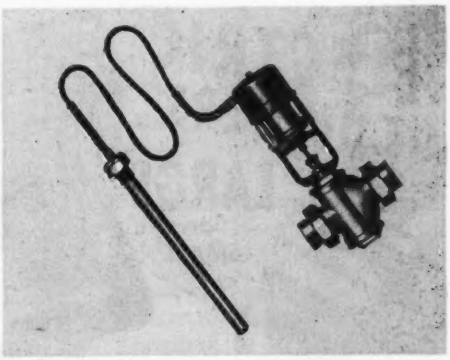

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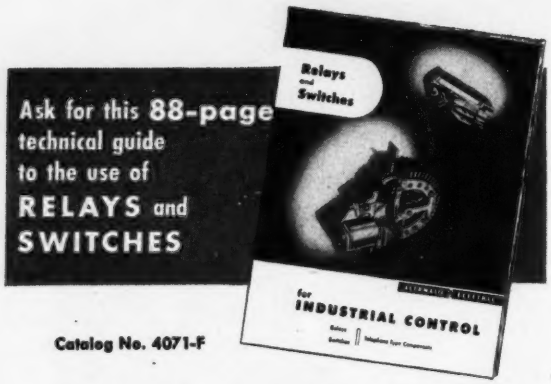
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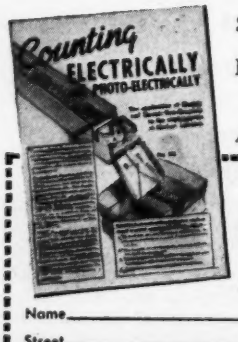

Standard, Panel Mounting and *Dustproof* Types.

For *built-in* applications, *photo-electric, remote,* and *central-ized production* counting.

Almost *any* voltage, AC or DC.

PRODUCTION INSTRUMENT CO.
702 W. Jackson Blvd., Chicago 6, Ill.

Send catalog of Wizard Electric and Photo-Electric Counter applications.

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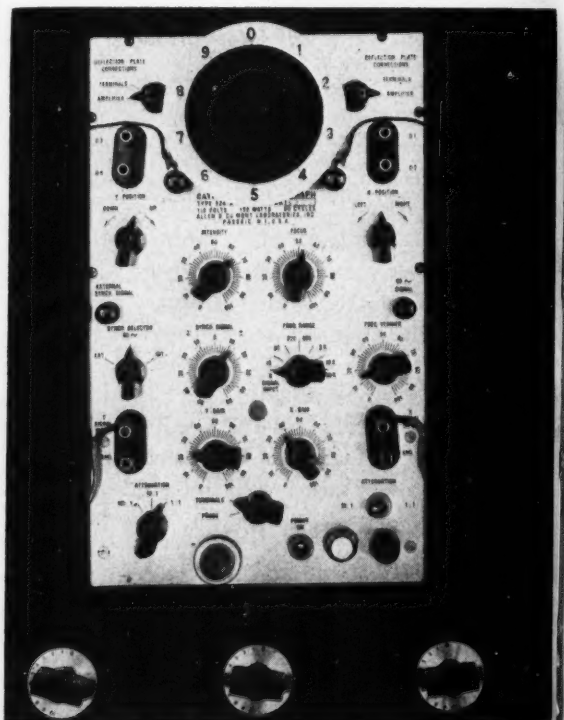
W-14

high-voltage pulses to the smaller drum and the tenths position are noted visually.

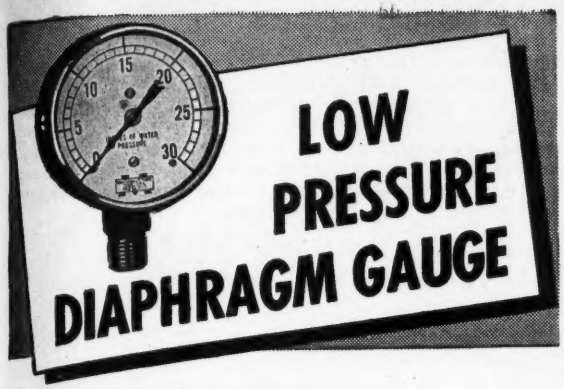
Since the chronograph records only to 0.5 millisecond, the chronoscope was developed primarily as a vernier device to permit the determination of long intervals with greater accuracy. In this instrument, the output of one crystal clock and frequency divider is used to produce a circular sweep with small, fixed marker dots on the face of a 3-inch cathode-ray tube. A pulse from another crystal clock produces a large bright spot on the sweep. By observing the position of this spot in relation to the marker dots, it is possible to measure relative time changes within a very small fraction of the interval required for one circular sweep. The time base and marker frequencies are obtained from the same frequency dividers that supply the chronograph drive so that the chronograph and chronoscope are locked in time phase just as are the minute and sweep-second hands of a conventional clock mechanism.

The circular sweep is obtained by applying 100-cycle voltages in phase quadrature to the deflection plates of the cathode-ray tube. The grid of the cathode-ray tube is biased below cut-off so that no trace appears on the face of the tube except when a positive pulse is applied with sufficient amplitude to let the tube conduct. A 10-kc signal produces a circle composed of 100 dots, each 0.1 millisecond apart. Reference points are produced by a 1-kc sine wave shaped to give negative pulses just wide enough to blank out every tenth one of the 10-kc dots. The signal to be measured is fed as a strong positive pulse which places an enlarged dot on the face of the tube. The entire circular sweep represents 0.01 second while distance between dots corresponds to an interval of 0.1 millisecond. By estimating fifths between the small dots, the position of the larger dot may be determined with sufficient accuracy to measure the change in relative time, as kept by two clocks, within 0.02 millisecond.

For greater resolution a larger cathode-ray tube may be used to increase the span between adjacent markers. For



The chronoscope is designed to operate with the spark chronograph as a means for measuring relative time differences between any two crystal clocks of the NBS. Day-to-day variations in relative time may be determined within a millisecond by change in displacement on chronograph chart, and within 0.02 millisecond on chronoscope. Tube face shows 10 groups of nine dots, each group separated by a blank space. A voltage pulse from the chronograph causes a brightening of a dot or space thus giving a time indication. Numbers surrounding c-r tube correspond to millisecond readings of chronograph.



MARSHALLTOWN Figure 83 is a very sensitive instrument utilizing a diaphragm for pressure communication, and is recommended for extremely low pressure service.

The following standard dials reading in inches of water are available—0-15" 0-30" 0-60" 0-100" 0-150".

Ounce graduated dials can also be supplied in a range from 16 ounces to five pounds.

It is available in the 2½", 3½", and 4½" dial sizes and mounted in a black enameled, deep steel case. Write for details and price.

MARSHALLTOWN manufactures one of the most complete lines of indicating pressure gauges—there is a Marshalltown gauge for every purpose and pressure.

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THERMAL CONTROLS
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WELL TYPE MANOMETERS

• Meriam Manometers in the laboratory of the North American Mfg. Co., Cleveland, Ohio, well-known makers of combustion equipment for gas and oil.

These manometers are *direct reading*. They save time — no additions. Likewise, prevent error. This greater ease and speed in reading have made them very popular throughout industry — in both plant and laboratory.

In the illustration the manometers measure the upstream pressure at the orifice plates in gas and air lines leading to equipment under test. At test stations in this plant they also measure the pressure of gas and air for test units.

Other industrial uses are for measuring vacuum pressures in tanks, setting gas pilots, reading pressures at blowers. In testing laboratories they are extensively used in measuring the pressure and vacuum of practically all kinds of liquids and gases. Complete information on request.

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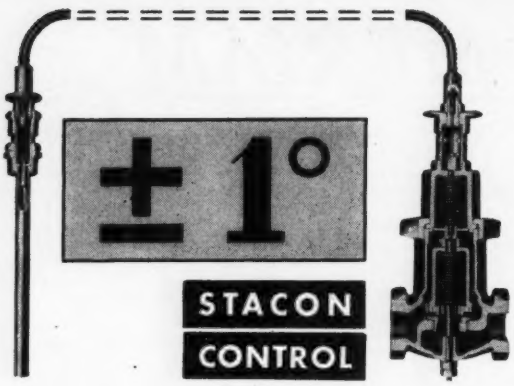

Temperature regulation to plus or minus one degree F. is the unheard-of accuracy obtainable with the self-operated Farris Stacon Temperature Regulator.*

Two design factors are responsible:

1. Liquid in bulb flashes to vapor in power bellows — steam does 99 per cent of the work...without appreciable time lag.
2. Full balancing bellows has the effect of double seated operation with single seated valve — eliminates spring counterpoise and all packing glands. provides free-floating valve disc. prevents response to variations in steam temperature.

Stacon Regulators are compact, trouble-free, dirt-proof. They operate consistently in the worst possible surroundings and require no maintenance.

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* PATENTED

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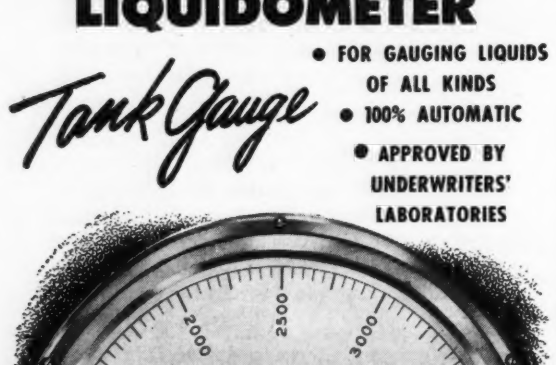
LIQUIDOMETER

Tank Gauge

- FOR GAUGING LIQUIDS OF ALL KINDS
- 100% AUTOMATIC
- APPROVED BY UNDERWRITERS' LABORATORIES



WRITE FOR COMPLETE DETAILS

THE LIQUIDOMETER CORP.

3627 SKILLMAN AVE., LONG ISLAND CITY, N.Y.

greater accuracy, 100-kc markers could also be added. Another possibility is the use of a second chronoscope starting with either a 1-kc or 10-kc time base and using 100-kc or 1-Mc markers to permit higher resolution.

Precise measurements of time and frequency are becoming increasingly important for example, in long-range radio navigation systems, in the upper range of the microwave region where atomic systems can serve as electronic components, and in basic research in microwave spectroscopy and molecular structure.

New Weather-forecasting Techniques with G-E Analytical Mass Spectrometer

SCHENECTADY, N. Y.—Scientists of the Geophysical Research Directorate, a branch of the Air Force Cambridge Research Laboratory, have announced that information being obtained by means of an instrument called the analytical mass spectrometer will be used in new studies of the composition of the earth's atmosphere. The studies, they explained, may lead to the development of new weather-forecasting techniques.

They emphasized that the high-sensitivity range of the mass spectrometer which was designed and built in the General Electric Company's General Engineering & Consulting Laboratory at Schenectady, N. Y., will aid in the study of reactions which meteorologists believe take place among constituents of the atmosphere as a result of absorption of radiant solar energy. It was pointed out that the studies are still in the preliminary stages.

G. E. engineers added that the mass spectrometer is so sensitive that under some conditions it can detect a gas which is only 1/100,000 part of another gas. Because it separates molecules of different masses, the instrument is useful in recording presence of isotopes, particles which react chemically in the same way but differ only in mass and atomic structure. Scientists of the Cambridge Air Force Laboratories will use the instrument to seek upper-atmosphere isotopes which have not yet been discovered.

CAA Finds "Picture" Instruments Better for Pilots than Symbolic

WASHINGTON, D.C.—Aircraft instruments which give a pictorial display enable pilots, both skilled and unskilled, to navigate better than those which give a symbolic display, a research report to the Civil Aeronautics Administration has revealed.

Using an instrument which shows the position of the plane on a "picture" which also shows its destination, 15 private pilots and 15 pilots with instrument ratings flew 407 navigation problems without a single unsuccessful solution. The same pilots, using instruments that gave a symbolic display, flew 439 similar navigation problems, of which 50 were not successfully solved within the time allotted.

Most airplane instruments today are of the symbolic type. That is, they indicate with needles and pointers to the pilot that he is on or off his course or altitude, or that his equipment is operating normally or abnormally. To interpret these indications, he must translate these "signs" into usable knowledge, such as which way to turn to get on the proper course. In the pictorial style instrument, the plane is shown in positive relation to the destination, the range station and the compass course the pilot desires to fly. Little or no interpretation is required, and proper corrective action usually is automatic.

The study is the fourth made in comparing the two kinds of instruments, and results have been uniformly in favor of the "picture" type instrument. The latest study, con-

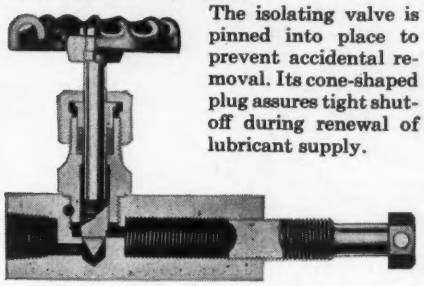
COMPARE

THIS FEATURE

OF THE HONEYWELL SERIES "700" VALVE

SAFETY STEM LUBRICATOR

The Stem Lubricator of stainless steel bar stock has an isolating valve for maintaining safe conditions *at all times.*



The isolating valve is pinned into place to prevent accidental removal. Its cone-shaped plug assures tight shut-off during renewal of lubricant supply.

Specially Designed Neoprene Diaphragm

Duplex Upper Stem Guide

One-Piece Bonnet

Packless Bellows Seal

Wide Variety of Discs

Reversibility in the Field

* Compare the Safety Stem Lubricator of this valve with that of any other wide band proportional type. Look at it closely . . . study it feature by feature.

Then check the other features of the valve . . . the Specially Designed Diaphragm, the Duplex Stem Guide, the One-Piece Bonnet, the Packless Bellows Seal, the wide variety of discs, the easy reversibility in the field.

Your comparison will prove that the Honeywell Series 700 has *all* of the features you look for in a fine valve.

It's available in a wide range of styles and sizes. For detailed information, write for a copy of Bulletin 700-2, or call in your local Honeywell engineer . . . he is as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 1908 Windrim Ave., Philadelphia 44, Pa. Offices in more than 80 principal cities of the United States, Canada and throughout the world.

New Bulletin 750, "Control Valve Sizing Data," is now available

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The Cambridge Fabric Permeameter is an accurate, rugged and convenient instrument for production testing of the permeability of fabrics which are to be inflated with Hydrogen, Helium, Carbon Dioxide, etc.

The rate of permeation through the fabric is quickly determined by equipment utilizing the thermal conductivity method and is indicated in terms of liters per square meter per 24 hours of the retained gas.

Manufacturers of fabrics for lighter-than-air Craft, Life Rafts, Life Jackets, Gas Masks, etc., will find this an indispensable instrument. Send for particulars.

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Features new ball bearing gear reduction motor, other refinements to make it the most efficient small parts cleaner. Triple nesting baskets fit larger basket to clean 3 sets of parts. List price, **$262.50**

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Foot rheostat controlled. Use with any flexible shaft tool attachment. 1/12 H.P., 115 volts, AC-DC. L&R Flexible Shaft Motor, cord set, rheostat and L&R No. 17 quick-detachable radial handpiece with No. 0 Jacobs Chuck.
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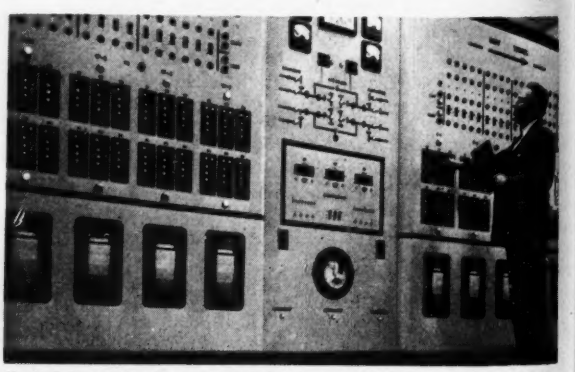
ducted at the University of Illinois under the auspices of the National Research Council Committee on Aviation Psychology, with funds provided by the CAA, involved problems connected with flying on the Very High Frequency omni-directional radio range. The pilots "flew" in a Link trainer in which the usual symbolic instruments and a specially-made pictorial instrument were installed.

Lighting-Ventilating Control in Brooklyn-Battery Tunnel

NEW YORK CITY—The 1.7-mile Brooklyn-Battery Tunnel, longest and deepest vehicular tube in the Western Hemisphere, is the latest link added to the complex chain of highways, bridges, and tunnels connecting the island of Manhattan to New Jersey, Long Island and the mainland New York.

On the Manhattan side, the West Side Highway and the East River Drive converge at the Battery entrance. A special underpass expedites traffic from West Side Highway to tunnel entrance and speeds traffic from East River Drive. In Brooklyn, the Gowanus Parkway funnels into tunnel, as does the Brooklyn-Queens connecting highway.

Lighting controls in the underground ventilation building and the Brooklyn pump room are enclosed in Trumbull Electric "NTQ" lighting panel boards. Manhattan Plaza signals and traffic signals over entrance portals are controlled from special relay panels. Trumbull contactor boxes control dampers in underground ventilation building. Speed of ventilating fans is regulated according to carbon monoxide detector readings continuously relayed to a General Electric control board in the Brooklyn service building.



Control board (by General Electric) in the Brooklyn service building.

Foreign Instrument Meetings and Exhibits

Below are listed foreign Fairs, Exhibitions and Meetings to be held in 1951 and of interest to those interested in instrumentation:

April 6 *to April* 11—Physical Society's 35th Annual Exhibition of Scientific Instruments and Apparatus, Royal College of Science, South Kensington, England.

Exhibits limited to new instrument developments. A very complete catalog of the instruments on display, containing full descriptions of all exhibits can be obtained from the Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7, England.

April 7 *to April* 17—Swiss Industries Fair, Basle, Switzerland.

This Fair has a large section devoted to instruments and precision devices built in Switzerland.

April 29 *to May* 8—German Heavy Industries' Fair, Hanover, Germany.

This fair also has many instrument exhibits. Exhibits are not limited to German manufacture.

April 30 *to May* 11—British Industries' Fair, London and Birmingham, England.

A large number of instrument manufacturers exhibit. Exhibits are limited to British manufacture.

May 15 *to May* 25—Gauge and Tool Exhibition (Gauge & Tool Makers' Association) London, England.

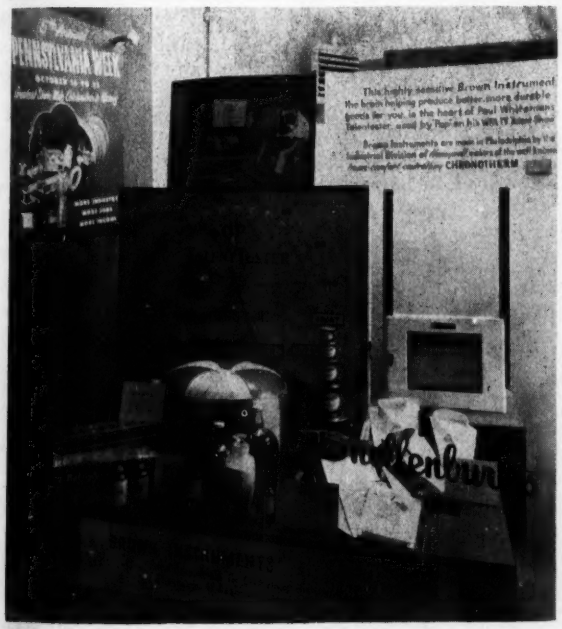
May 28 *to June* 8—Canadian International Fair, Toronto, Canada.

A large instrument exhibit is included.

July 4 *to July* 14—British Instrument Industries' Exhibition, London, England.

This is first instrument trade exhibition. Exhibits are limited to British manufacture.

July 16 *to July* 21—Automatic Control Conference, College of Aeronautics, Cranfield, Bedfordshire, England. For information write to Prof. A. Tustin, Professor Electrical Engineering, University of Birmingham, Birmingham, England.



Window display used by Snellenberg Department Store in Philadelphia during Pennsylvania Week shows passers-by the importance of industrial instruments in producing the variety of consumer items in use today.

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NEW GILBARCO INSTRUMENT HOUSINGS

offer low-cost solution to housing problem for petroleum and chemical industries

Feature complete protection and accessibility

1. **Die-formed of auto body steel.**
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4. **For wall mounting, horizontal pipe or pedestal pipe mounting.**
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6. **Pipe clamps available for instrument installation.**

(Made in four sizes.)

MULTI-PURPOSE USEFULNESS... Gilbarco cabinets are used for housing process control instruments, outdoor control valves, small vertical pumps, fire blankets, weather stations, outdoor interplant phones, bulk terminal gauges, other industrial housing needs.

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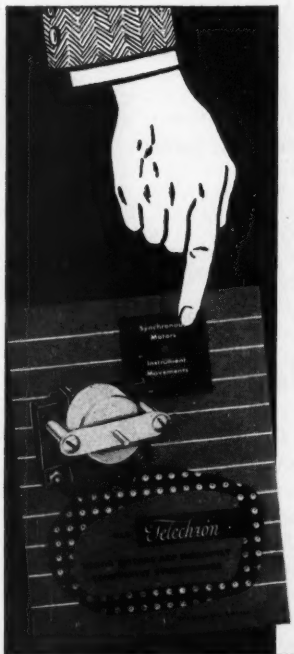

TIMING PROBLEM?

THIS NEW MOTOR BULLETIN gives you the torque ratings, specifications, drawings and application data on TELECHRON synchronous motors. The 50,000,000 TELECHRON motors used in instruments, timers, electric clocks, cost recorders, cycle controllers, etc., in the past 30 years are your guarantee of accurate, dependable, long-lived service. WRITE FOR BULLETIN IS-110. TELECHRON INC., 63 UNION ST., ASHLAND, MASS. A GENERAL ELECTRIC AFFILIATE.

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Now you can make tube and pipe connections at 1000 psi and above with . . .

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FITTINGS

The patented design of the Weatherhead Ermeto Fitting permits installation with no tools but a wrench, easy disassembly, and retightening with a pressure-tight joint.

Ermeto meets S. I. C. requirements

Meeting Aircraft Requirements Makes *Quality* A Weatherhead *Habit*

Research in vibration has taught us how to distribute loads, avoid stress points. Research in high pressure has taught us the design and metallurgical factors which mean safety up to 40,000 psi. Constant laboratory work at high and low temperatures has taught us what to expect in joints under all temperature conditions. Serving the needs of many industries has aided us in developing fittings for the high demands of corrosion resistance.

This knowledge, as it helps solve aircraft and other special problems . . . where fittings demands are extreme . . . also has guided the design and production of all the fittings that are "standard" in the Weatherhead line.

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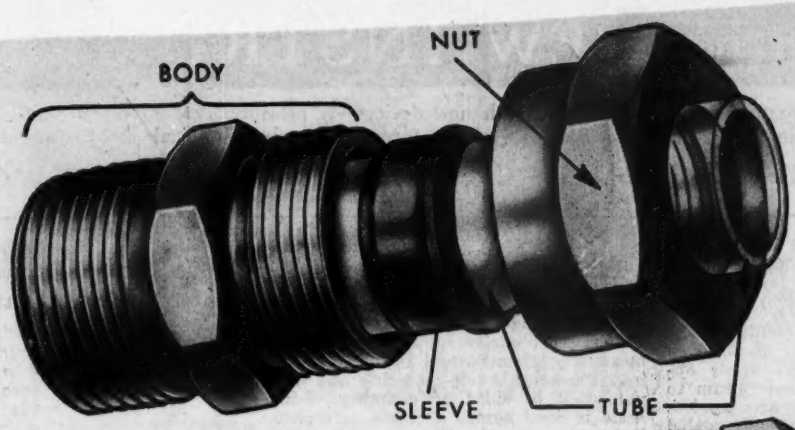
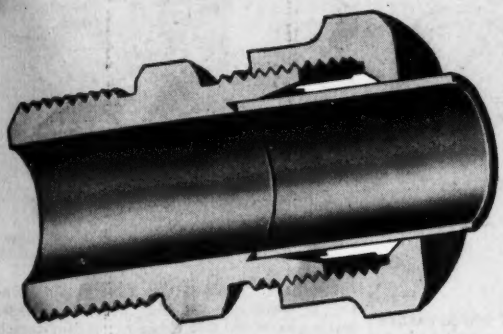
FIRST IN HYDRAULIC CONNECTIONS

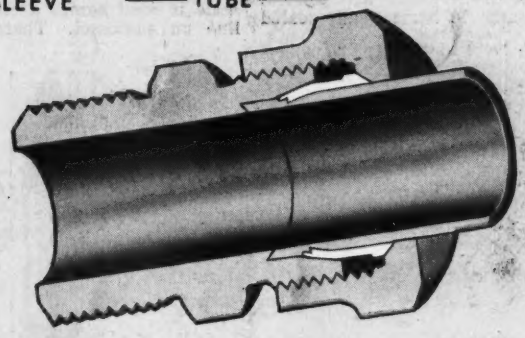
Plants at Cleveland, Ohio; Angola and Columbia City, Indiana; and St. Thomas, Ontario



1 The hardened sleeve is the heart of the Ermeto fitting. The sleeve and nut are slipped on the tube; end of tube is inserted into body of fitting.



2 As nut is tightened, the pilot of the sleeve contracts, engaging outer surface of tube.



3 Fully tightened. Tube end butts tight against body shoulder.

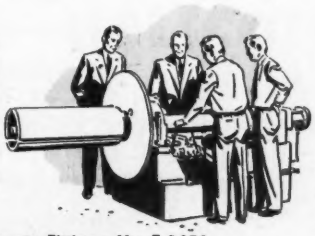
Nut presses sleeve bevel, causing entire sleeve to clamp the tube. This strengthens seal and distributes vibration strains.

Forces acting on sleeve cause it to bow slightly, giving it a spring action which holds constant tension between the body and the nut—prevents loosening.

DESIGNED for high-pressure use, the Ermeto fitting has so simplified and cut costs on all tube connections that many manufacturers are standardizing on ERMETO FOR ALL JOINTS. The advantages in terms of simplified inventories, are obvious. Made in steel, stainless steel and brass—sizes from ⅛" to 2" O. D. Get full information now! Write on company letterhead for catalog #E-1457. The Weatherhead Company, Dept. S, 300 East 131st Street, Cleveland 8, Ohio.

DESIGN ENGINEERS—can forget psi when they specify... ERMETO! Meets J. I. C. requirements. Designed for high pressures, economical for low pressures because of simplified inventory when used for all joints!

PRODUCTION AND MAINTENANCE ENGINEERS—Ermeto installs quick and easy—no tools but a wrench. Easy to take apart and can be retightened with a pressure-tight joint. No production holdups due to involved flaring, threading, welding or soldering of joints.



Get complete details now—write for catalogs No. E-1457 on Ermeto Fittings, No. F-1456 on Standard Weatherhead Fittings and No. H-1451-A on Hose Assemblies and Reusable Hose Ends. ***Address—The Weatherhead Company, Dept. S, 300 East 131st Street, Cleveland 8, Ohio.***

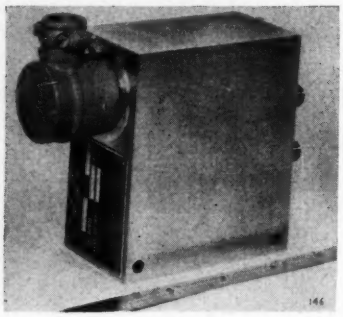
The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

FOR FURTHER INFORMATION USE THE POSTAGE-FREE ORDER CARD ON PAGE 353

SR-4 Differential Pressure Cell

New "Type FMB" differential pressure cell consists of a pair of matched Monel metal bellows which apply opposing forces on a cantilever beam to which SR-4 strain gages are bonded. Sensing element is hermetically-sealed

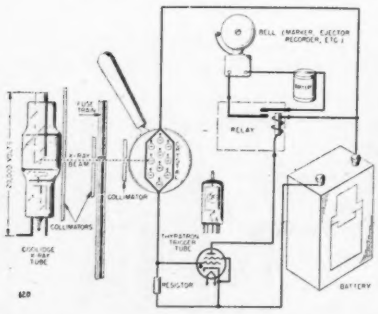


in an aluminum box; electrical connections are made through glass-to-metal seals. Cell is insensitive to linear acceleration and may be mounted in any position. Differential ranges of 10 and 20 psi. are available with maximum pressures of 50 and 100 psi. respectivity. Cells are designed for standard 120-ohm circuit and for 300-ohm circuits. Output at rated differential is 2 mv. per v. input; cells are temperature compensated for zero and span. Accuracy is 0.25 percent of full scale.—*Baldwin-Lima-Hamilton Corp., Philadelphia, Penna.*

Mention No. 301 when filling out card.

X-ray Crystal Detector

New semi-conductor crystals have been developed as X-ray detectors. When excited by low-intensity X-rays,

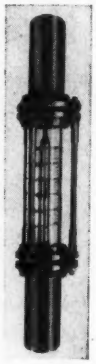


crystals pass current which can be used to operate counters, signals, or alarm circuits.—*General Electric X-ray Corp., 4855 Electric Ave., Milwaukee 14, Wis.*

Mention No. 302 when filling out card.

Liquid Density Indicator

New model of "Densitrol" liquid density measuring instrument uses a totally submerged chain weighted plummet as measuring element and is direct reading. Plummet is self-centering and will not stick to sides of chamber. 5-in. scale is read across a single reference line on plummet. Thermometer cali-



brated directly in terms of temperature correction can be mounted on chamber. Instruments can be constructed from a wide variety of materials with maximum ratings of 125 psi. and 300 C. Calibrated range must be within limits of 0.5 to 3.5 density or equivalent.—*Precision Thermometer & Instrument Co., 1400 Brandywine St., Philadelphia 30, Penna.*

Mention No. 303 when filling out card.

Oil-burner Flame Failure Control

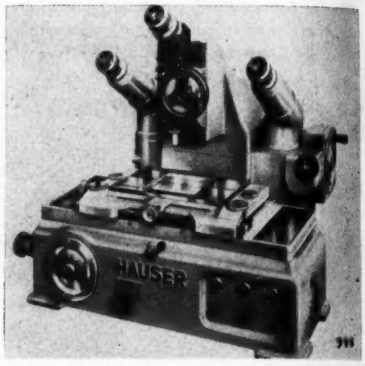
New flame failure control for oil-burners has an electrode unit for gas-pilot flame detection, and a photoelectric unit for the main flame. When unit

operates to cut off fuel nozzle or cup is purged before system locks out. Manual reset is required to restart unit. Built-in contactor controls motors to 0.5 hp. 110 v. 60 cps.—*Control Div., General Electric Co., Schenectady 5, N. Y.*

Mention No. 304 when filling out card.

Tool-room Measuring Instrument

New "Type P324" precision measuring instrument has longitudinal and transverse ranges of 4 in. Measuring table 9.5 x 6 in. has zero-setting feature. Microscope reads directly to 0.00005 in.; measuring microscope is



interchangeable with goniometer; centering microscope is interchangeable with graticule for locating center-punch marks. Center punch fits concentrically with microscope carrier. Light source operates on 125 to 220 v. Weight is 340 lbs.—*Hauser Machine Tool Corp., Manhasset, N. Y.*

Mention No. 305 when filling out card.

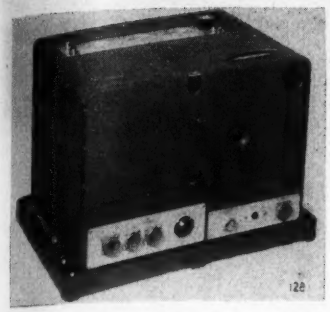
Roll-temperature Measuring Element

New roll-temperature measuring element does not touch roll, but measures temperature of air film adhering to roll. Unit mounts 0.032 in. from roll and sucks air stream from roll past primary element. Suction rate and roll speed are non-critical over wide limits, maker states. Unit is applicable to rolls over 9 in. diameter and flat surfaces; measurement is within 4 deg. F. of true temperature.—*Leeds and Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa.*

Mention No. 306 when filling out card.

Multi-channel Photographic Recorder

New "Mirragraph" records 13 channels on 35-mm. film. Input voltage range is 0.005 to 0.5 v. rms. at 1000 cps. with a useful frequency range of 0 to 6000 cps. Film magazine capacity is 200 ft.; motor drive operates on 24 to 28 v. d.c. Reproducing equipment has film speeds of 6, 12, and 18 in.;



output is 0.009 v. rms. into 600-ohm load. Also available are Model "3A" frequency analyzer and "Model 4A" level recorder.—*Techno Instrument Co., 6666 Lexington Ave., Los Angeles 38, Calif.*

Mention No. 307 when filling out card.

Aircraft Fuel Flowmeter

New flowmeter consists of panel mounted indicator-totalizer (Fig. 1) operated by electrical transmission from positive displacement meter. Knob re-

Fig. 1

sets totalizer to zero. Displacement meter (Fig. 2) for internal combustion engines has electrically-operated by-pass valve; for smaller-type jet engines

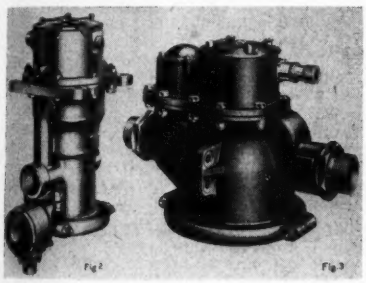


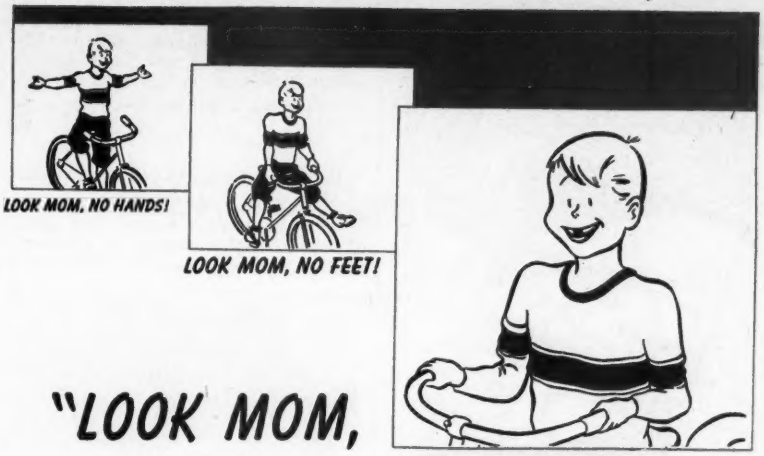
Fig. 2 Fig. 3

by-pass valve operates automatically when meter capacity is exceeded. Fig. 3 shows meter for larger-type jet engines.—*C. F. Carpenter, 11 W. 42nd St., New York 18, N. Y.*

Mention No. 308 when filling out card.

Automatic Pilot for Jet Planes

New automatic pilot for jet planes features non-tumbling gyroscopes which respond to rate of change of plane's angle. Instrument controls plane under pilot's direction during complicated maneuvers and can take complete control during level flight. Unit can also



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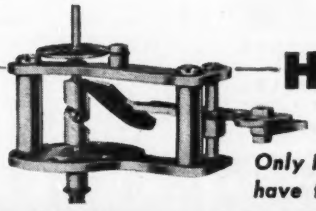

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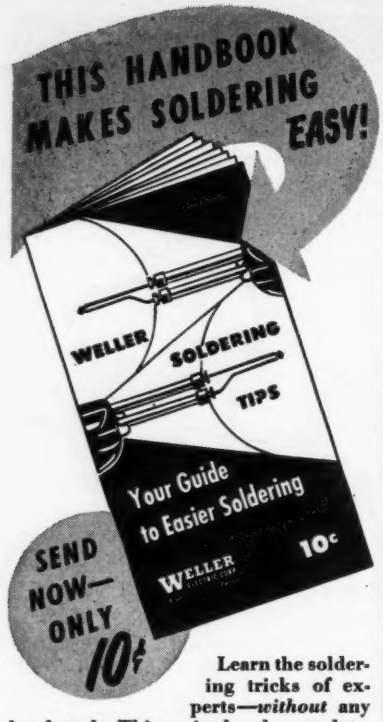

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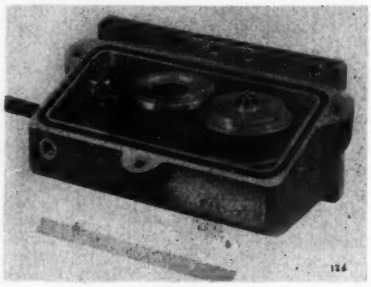
be tied in to plane's radar and instrument landing systems.—*Westinghouse Electric Corp., 306 Fourth Ave., Pittsburgh 30, Pa.*

Mention No. 309 when filling out card.

Recording Accelerometer

New "Type E-62" accelerometer has a built-in magnetic tape recorder. Motion of seismic mass causes a permanent magnet to erase part of an HF carrier

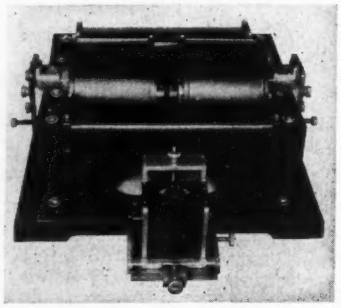


magnetization on tape. New "Type E-57" playback unit also records carrier, and has a c-r. oscilloscope for viewing signal. Seismic elements are available with resonant frequencies from 230 to 1600 cps.—*Instrument Div., Engineering Research Associates, Inc., 1902 W. Minnehaha Ave., St. Paul W4, Minn.*

Mention No. 310 when filling out card.

Permeameter

New "High-H" permeameter consists of an electromagnet assembly with specimen holding device and test coil system, control box, galvanometer, and accessories. Features of instrument are



direct-reading calibration system, remote-controlled flip-coil system, double H-coil, and remote-controlled reversing switch in magnetizing circuit. Accuracy is 1 percent when magnetizing force is above 100 oersteds.—*Dep't E, Rubicon Co., Ridge Ave., at 35th St., Philadelphia 32, Pa.*

Mention No. 311 when filling out card.

Calibrating Pulse Generator

New "Model D1" pulse generator has outputs available with pulse spacings from 10 to 200,000 microseconds generated by blocking oscillators. Wider pulses are provided by a single-shot multivibrator at spacings of 1000, 10,000, and 100,000 microseconds. Width

of pulse is function of repetition rate. Over-all dimensions 9 x 19.5 x 15 in.—*Rutherford Electronics Co., 3724½ S. Robertson Blvd., Culver City, Calif.*

Mention No. 312 when filling out card.

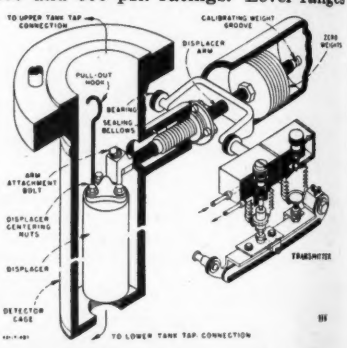
Recorder with Adjustable Range and Zero Suppression

New "Speedomax" recorder has d-c. millivolt range adjustable from 1.1 to 22 mv. across-chart span. Uncalibrated coarse and fine rheostats provide maximum zero suppression of −50 to 50 mv. Range and zero suppression adjustments are independent.—*Leeds and Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa.*

Mention No. 313 when filling out card.

Liquid-level Transmitter

New displacement-type liquid-level transmitter is standard with stainless steel displacer; cage is cast steel with 300 and 600 psi. ratings. Level ranges



are available to 120 in.; specific gravity beam is calibrated 0.3 to 2.0. Pilot and damping bellows are stainless steel; operating lever is bellows-sealed to atmosphere.—*Brown Industrial Div., Minneapolis-Honeywell Regulator Co., 4482 Wayne Ave., Philadelphia 44, Pa.*

Mention No. 314 when filling out card.

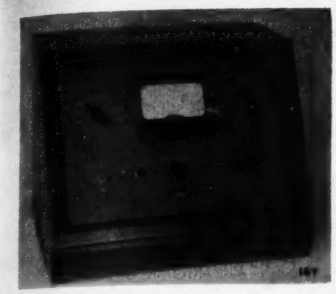
Testing Machines

New "Super L" testing machines feature a range selector system separate from loading system. Three test ranges of full, 0.2 and 0.02 of capacity are indicated in different colors on same dial with zeros for all ranges identical. Test ranges may be changed during a test without changing rate of loading. Load is applied by a hydraulic piston and cylinder in base of machine. Testing speeds range from 0 to 2 in. per min. in stepless intervals. Units are available with ranges of 60,000, 120,000, 200,000, and 300,000 lbs.—*Tinius Olsen Testing Machine Co., 1116 Easton Road, Willow Grove, Pa.*

Mention No. 315 when filling out card.

Microsecond Timer

New "RC Intervalometer" measures intervals from 1 microsecond to 0.1 second; instrument uses an RC network and cathode follower stages. Accuracy

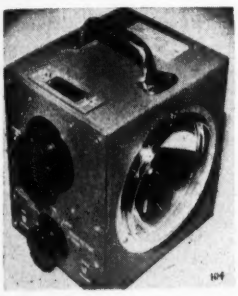


is 3 percent above 10 microseconds; power supply is internally regulated. Over-all dimensions 12 x 12 x 18 in.; weight 25 lbs.—*Nelson and Street, P. O. Box 4342, Takoma Park, Washington 12, D. C.*

Mention No. 316 when filling out card.

Stroboscopic Tachometer

New "Model 351A" stroboscopic tachometer has a range from 600 to 14,400 rpm.; can be extended in both directions. Accuracy is 1 percent above 900

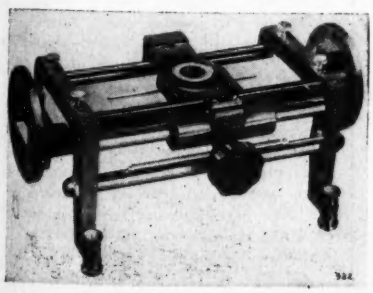


rpm. Instrument operates on 105- to 125-v. 50- to 60-cps. line; over-all dimensions 7.5 x 8.75 x 10 in.; weight 9.5 lb.—*Electronic Measurements Co., Red Bank, N. J.*

Mention No. 317 when filling out card.

Waveguide Test Equipment

New line of waveguide test equipment provides full frequency coverage from 2.6 kmc. to 18.0 kmc. in 6 waveguide sizes. "Model 809B" precision carriage accepts either slotted waveguide or coaxial sections covering frequencies from 4.0 to 12.4 kmc. Carriage travels on a system of three-point con-



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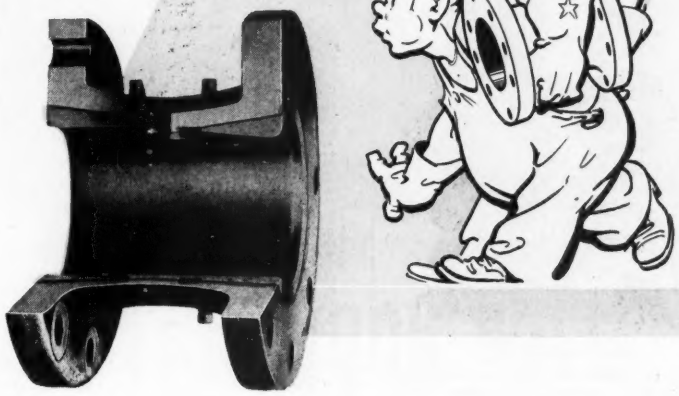

The picture above sectionalizes one of our standard 12 inch Foster Flow Tubes. Put a rule on it, lengthwise and diametrically. What do *you* make the length-diameter ratio? About 1½ to 1?

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Yes, you get great compactness and ease of installation with the Foster Flow Tube. You also can count on satisfactory accuracy. As for your specific applications, write us in detail giving both processing and installation requirements. Standard sizes come in all commercial pipe diameters, flanged or screwed connections. Standard lining is bronze; other metals to order.

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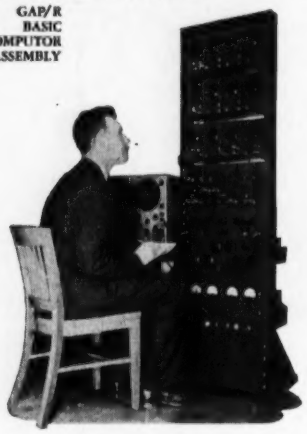

SPECIFICATIONS

Components: Regulated Power Supply, Central Chassis, Plug Panel, Rack and Accessories, 12 K3 Components (5 K3-C Coefficient Components, 3 K3-A Adding Components, 3 K3-J Integrating Components, 1 K3-L Unit-lag Component).
Excitation: Compound square-wave based on 0.004-second intervals. Connections provided for other forms of excitation.
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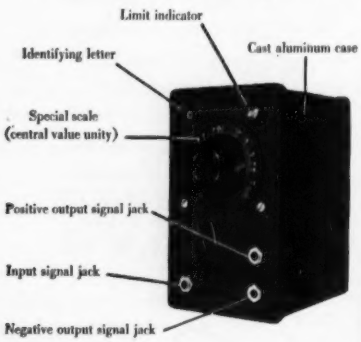

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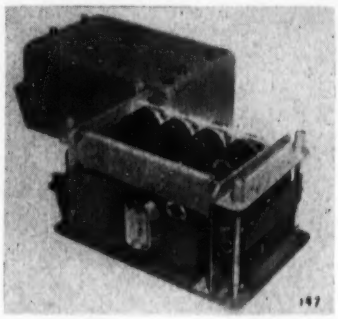
tinuous ball-bearing suspension. "Model 810B" waveguide slotted sections for carriage are available in four sizes. Items in new line include attenuators, tees, tuners, signal generators, power and frequency meters, etc.—*Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif.*

Mention No. 318 when filling out card.

Servomechanism Amplifier

New "Model SA-203" amplifier has plug-in networks for control of a 60-cps. two-phase servo-motor of 5 watts output. Unit contains input, phase-shift



and damping circuits, voltage amplification and an output power stage coupled to motor. Instrument operates on 115 v. 60-cps. line.—*Servomechanisms, Inc., Old Country and Glen Cove Roads, Mineola, N. Y.*

Mention No. 319 when filling out card.

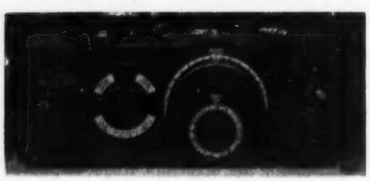
Calibrating Unit for Polarographic Analysis

New calibrating unit is used with a potentiometer, galvanometer, and electrodes, for manual polarographic analysis. Instrument calibrates galvanometer to provide direct readings of diffusion current in test solution. Switch provides ranges from 1 to 100 microamp.—*Leeds and Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa.*

Mention No. 320 when filling out card.

Bridge Oscillator

New "Type 1330-A" bridge oscillator has AF outputs of 60, 400, and 1000 cps. and variable RF output from 5 kc. to 50 Mc. either modulated or un-



modulated. Output is 10v. and 1 watt can be delivered into a 50-ohm load. Internal modulation at 400 or 1000 cps. is available from 15 kc. to 50 Mc. Overall dimensions 7.5 x 21.75 x 11.25 in. Instrument operates on 115 or 230 v. 40-60 cps.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 321 when filling out card.

Bridge-stabilized Oscillator

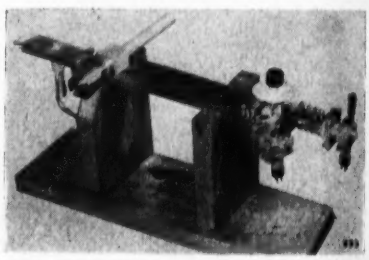
New "Model M-2" oscillator covers range from 1 cps. to 120 kc. in five bands. Calibration is within 1.5 percent plus 0.1 cycle of indicated frequency. One output circuit delivers 0 to 20 v. into 1000 ohms; second circuit

has internal impedance of 300 ohms, with output variable from 0 to 1 v. rms. Hum and microphonics are below 0.1 percent of output signal; harmonic distortion is 0.2 percent at AF and below 1 percent at higher frequencies. Power supply is internally regulated; over-all dimensions 9.75 x 18.5 x 12 in.—*Southwestern Industrial Electronics Co., P. O. Box 13058, Houston 19, Tex.*

Mention No. 322 when filling out card.

Sweeping Oscillator

New "Super-Sweep" oscillator has a frequency range from 500 to 2000 Mc. with sweep width 30 Mc. and up. Output is 0.5 v. maximum from 50 ohm



impedance. An absorption type wavemeter measures and sets frequency. Variable output attenuator covers range of 30 db; output is flat within 0.1 db per Mc. while sweeping.—*Kay Electric Co., Pine Brook, N. J.*

Mention No. 323 when filling out card.

Medium size old established manufacturer of full line of Industrial and Dairy Thermometers, Dial Thermometers, Recorders, Air and Electric Recording Controllers including Self Operating units, all with wide variety of ranges, and doing business nationally, would like to associate itself with another company of national scope who feels the need for broadening its' line by the addition of other instruments to meet their customers' and industry's requirements, with a view to merging ideas and consolidating or discussing suitable national sales arrangement. Box 192, Instruments Publishing Co., 921 Ridge Ave., Pittsburgh 12, Pa.

Tube Tester

New "Model 3413-A" tube tester has flexible 3-position lever switches with RMA pin numbering of tube element levers. Unit has an illuminated roll

type tube chart. Line voltage is indicated on center of 6 in. meter dial; filament voltages from 0.63 to 110 v. can be selected in 14 steps. Over-all dimensions 15.38 x 11 x 6 in.—*Triplett Electrical Instrument Co., Bluffton, Ohio.*

Mention No. 324 when filling out card.

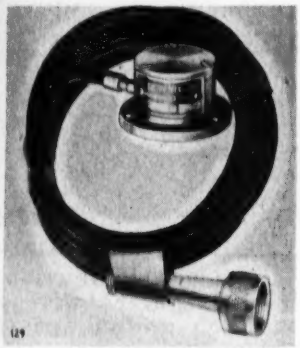
Locomotive-tachometer Test Equipment

New equipment for testing speed-sensitive devices on road locomotives consists of speed-controlled portable axle generator drive which operates from locomotive's battery circuit. Portable electric frequency meter is used to indicate shaft speed; a cps. scale provides information for setting automatic-transition relays.—*General Electric Co., Schenectady 5, N. Y.*

Mention No. 325 when filling out card.

Piezoelectric Accelerometer

New "Model A403" accelerometer has an acceleration range from 0.1 to 600 g; resonant frequency is 8 kc.; sensi-

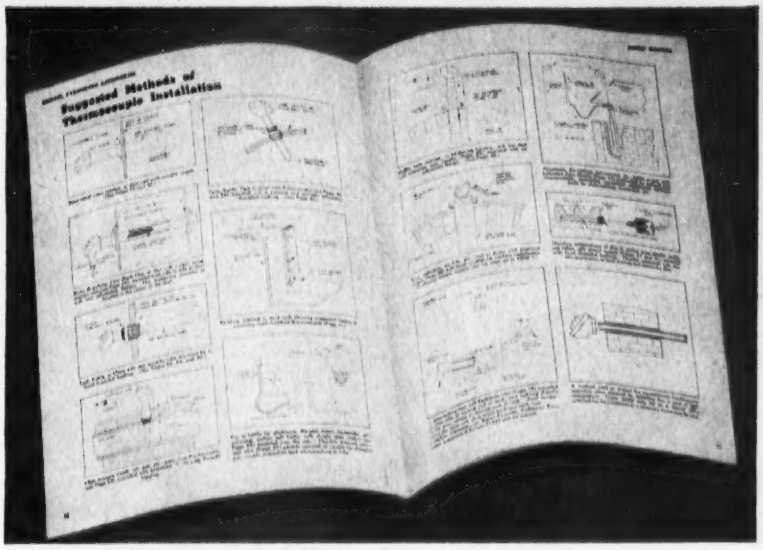


tivity is 10 mv. per g. Useful frequency range is 3 to 4000 cps. with maximum directivity perpendicular to mount. Size is 1.44 in. diameter by 0.75 in. long; weight 1 oz.—*Gulton Mfg. Co., Metuchen, N. J.*

Mention No. 326 when filling out card.

Pulse Generator

New "Analog Digital Converter" operates by mechanically rotating input shaft and supplying 85 v. d.c. to internal solenoid system. One revolution



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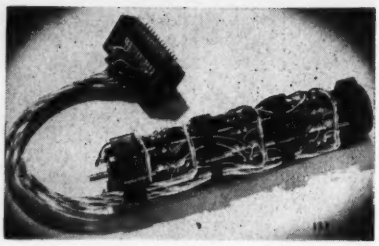


of input shaft provides ten output pulses. Repetition for given position of input shaft is within 0.25 of smallest increment of measurement. Counting both up and down scale without loss of position is accomplished by direct external and internal mechanical coupling not dependent on pulse count. Decades may be added providing count from 0 to 9 with one decade or 00000 to 99999 with five decades. Input torque requirements are 1.5 in.-oz.—*Genisco, Inc., 2233 Federal Ave., Los Angeles 64, Calif.*

Mention No. 327 when filling out card.

Detent-action Continuous Inputuner

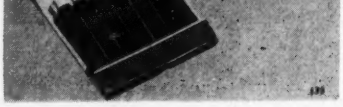
New "Series T3C" inputuner covers all TV and FM channels in four turns; one-knob operation clicks into any TV channel and then fine-tunes. Unit uses

a 3-gang spiral "Inductuner" with antenna tuning; available for sound center IF of 21.25 or 21.75 Mc. with or without sound trap.—*Electronic Parts Div., Allen B. DuMont Laboratories, Inc., East Paterson, N. J.*

Mention No. 328 when filling out card.

Miniature D-c. Motors

New line of miniature permanent-magnet d-c. motors are 1.25 in. diameter by 1.5 in. long and weigh 2.5 oz. Front-flange or base-mounting types



available; motor voltage ranges from 6 to 28 v. A cylindrical Alnico V field magnet is used with a 14-commutator-segment armature.—*Servo-Tek Products Co., Paterson, N. J.*

Mention No. 329 when filling out card.

Three-phase Induction Regulators

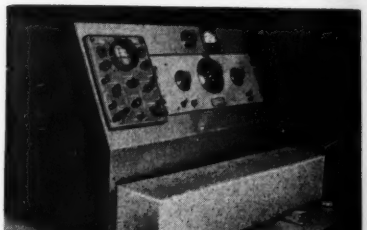
New line of three-phase dry-type induction voltage regulators includes self-cooled and forced-air-cooled units in standard 10 percent and 20 percent

(raise and lower) ranges of regulation. Range covers ratings from 120 to 600 v. and from 12 to 85 kva. Regulators are housed in an all-steel, ventilated cabinet.—*Transformer & Allied Products Divs., General Electric Co., Schenectady 5, N. Y.*

Mention No. 330 when filling out card.

AF Generator and Pickup

New "Electro Sonometer" supplies up to 18 watts at driving unit to measure resonant frequencies between 20 cps. and 22 kc. of solid masses weighing up to 1500 lbs. Phase relation between driving voltage and points within mass



"Instrument Development Engineer" with a thorough knowledge of pressure actuated mechanical instruments and allied devices and at least two years design experience on pneumatic controllers.

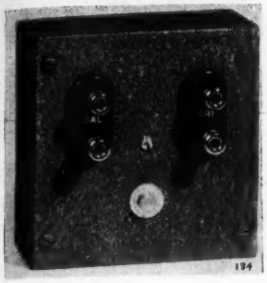
Firm located in southern New England. Write giving all pertinent data to: Box 191, Instruments Publishing Company, 921 Ridge Avenue, Pittsburgh 12, Penna.

can be viewed on c-r. oscilloscope and interpreted to determine Young's modulus.—*Electro Products Laboratory*, 4501 *Ravenswood Ave., Chicago* 40, *Ill.*

Mention No. 331 when filling out card.

Automatic Galvanometer Shunt

New "Model 170" galvanometer protector adjusts itself automatically during bridge balancing operation. Galvanometer retains enough sensitivity to



indicate balancing effect at all settings. but is protected against damage. Protector uses network of non-linear and linear resistors.—*Audio Instrument Co.*, 133 *W.* 14*th St., New York* 11, *N. Y.*

Mention No. 332 when filling out card.

Precision Potential Divider

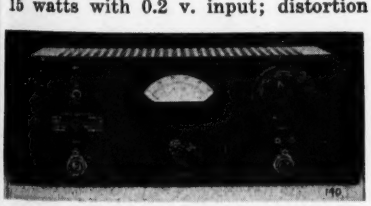
New "Type 162" precision potential dividers are available with single-turn linear and non-linear windings. Linear units have accuracy of 0.15 percent of

total resistance; non-linear units are accurate to 0.5 percent for most functions. Starting torque is 0.5 oz.-in. per unit; maximum resistance for linear units is 150,000 ohms.—*George Rattray & Co., Inc.*, 92-32 *Union Hall St., Jamaica* 5, *N. Y.*

Mention No. 333 when filling out card.

Power Amplifier

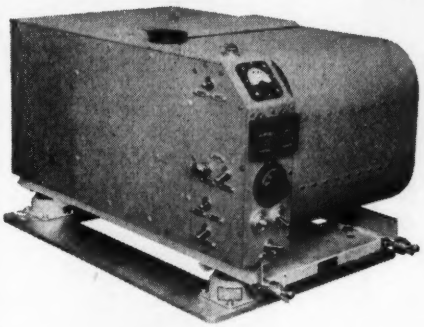
New "Type 1233-A" power amplifier has a frequency range from 20 cps. to 3 Mc.; maximum power output is 15 watts with 0.2 v. input; distortion



Century INDUSTRIAL

RECORDING OSCILLOGRAPH

FOR VIBRATION, TEMPERATURE, STRESS, STRAIN ANALYSIS



MODEL 408 OSCILLOGRAPH

The Century Model 408 recording oscillograph was designed expressly for airborne and mobile operation. As with all Century products, this oscillograph incorporates the utmost in design and workmanship, along with improved features, yet it remains simple in its operation and maintenance.

FEATURES:

Size: 20" long, 12½" wide, 8⅞" high.

Weight: 60 pounds.

Number of Recording Channels: 6 to 50.

Detachable daylight loading magazine accommodating a roll of paper or film 8" x 200'.

Friction roller type paper drive by governor controlled electric motor with separate motor for takeup drive.

Paper speeds continuously and instantly variable without changing gears or sprockets.

Separate optical system for viewing before or during recording.

Glow tube timing system photographing .01 second and .1 second lines. .01 second lines instantly removable by toggle switch for slower speeds.

Data numbering at beginning of record.

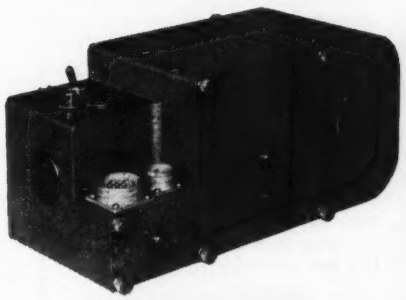
Footage indicator showing amount of paper remaining in magazine.

Automatic record length control.

Trace identification.

Remote control unit.

MODEL 409 OSCILLOGRAPH



The Century Model 409 oscillograph has been designed for recording data where space and weight requirements are limited. This oscillograph has been tested to record faithfully while subjected to accelerations up to 20 G's.

FEATURES:

Size: 5" x 5" x 11".

Weight: 11 pounds.

Cast Aluminum case.

Paper speeds variable ½" to 12" per second.

Detachable daylight loading magazine with a capacity of 3⅝" x 50' paper or film.

2 to 12 individual channels.

Trace identification.

Trace viewing.

For Complete Information Write 1340 North Utica

Century GEOPHYSICAL CORPORATION

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Philadelphia, Pa.

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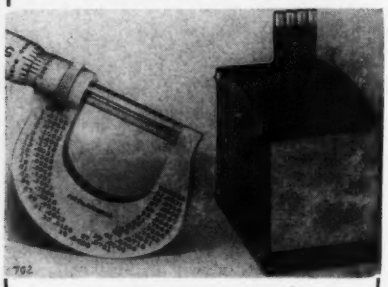


GALVANOMETER MODEL 106-SS

(SUPER-SENSITIVE)

● RECORDS FROM SOURCE WITHOUT AMPLIFICATION . . .

● BALANCE TO LESS THAN .001" PER "G" AT 12" OPTICAL DISTANCE.

A Super-Sensitive galvanometer especially developed by Midwestern for use in recording signals direct from source, without amplification. Because of its precision balance, it is especially valuable in applications where instruments are subjected to extreme vibration—such as in aircraft testing. No special shock mounting is normally required.

The regular production model balance of .003" per "G" is much better than any production models previously offered. For special applications of severe vibration conditions this galvanometer can be balanced to less than .001" deflection per "G". Also, the "bow-string" effect, present in some degree in most galvanometers, has been practically eliminated due to a new suspension design.

This galvanometer has individual circuits for both terminals of the elements. Element tube O.D. is .187", and length is 2.062". It is used in Midwestern's magnet structure M-153. Center distance between elements is .195". Characteristics of elements are shown below.

SS Type	Nominal Undamped Natural Frequency	D.C. Sensitivity 12" Optical Arm (Undamped) Ma/In.	Nominal Galvanometer Resistance Ohms
106-100	100	0.005	35
106-150	150	0.012	35
106-200	200	0.020	35

Write for Bulletin Osc. 12-50-C

MIDWESTERN
GEOPHYSICAL LABORATORY

2803 W. 40th • Tulsa, Oklahoma

is 3 percent of rated output on all ranges. Input impedance is 0.1 megohm shunted by 37 uuf. Output voltage is indicated on panel-mounted VTVM.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 334 when filling out card.

Vertical CRO

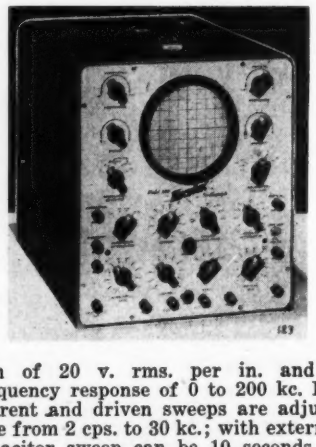
New "Model 476 Mirroscope" has a 5-in. c-r. tube mounted in vertical position. Image is reflected from mirror

mounted in adjustable cover at top of cabinet. Over-all dimensions 16.25 x 9 x 8 in.; weight 24 lbs.—*Simpson Electric Co., 5200 W. Kinzie, Chicago, Ill.*

Mention No. 335 when filling out card.

Five-inch CRO

New "Model 640" 5-in. c-r. oscilloscope has a frequency response from d.c. to 4.5 Mc. Vertical amplifier has deflections of 10 and 25 mv. per in.; horizontal amplifier has direct deflec-



tion of 20 v. rms. per in. and a frequency response of 0 to 200 kc. Recurrent and driven sweeps are adjustable from 2 cps. to 30 kc.; with external capacitor sweep can be 10 seconds or slower. Instrument has built-in calibrating voltages.—*Hickok Electrical Instrument Co., 10519 Dupont Ave., Cleveland 8, Ohio.*

Mention No. 336 when filling out card.

Oscilloscope Calibrator

New "Model A-42F" oscilloscope calibrator is a source of continuously variable monitored voltage from 0.0005 to 100 v. rms. It is calibrated directly in peak to peak volts and decibels as well as rms v. Unit is housed in a

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- **Autopilot Design**
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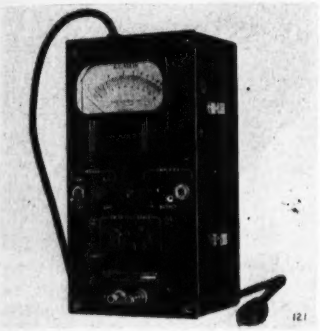
12214 South Lakewood Blvd.
Downey, California

molded bakelite case.—*Tensor Electric Development Co., Inc.*, 343 *Classon Ave., Brooklyn* 5, *N. Y.*

Mention No. 337 when filling out card.

Vacuum-tube Voltmeter

New "Type 170" VTVM covers a frequency range from 10 cps. to 250 kc.; input impedance is 0.5 megohm.

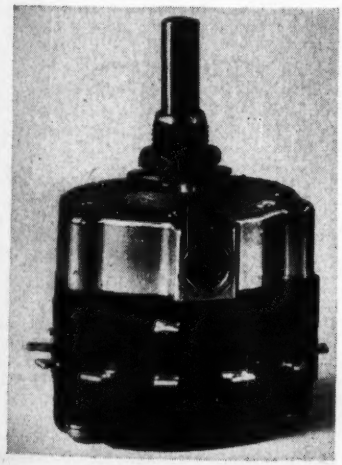


Instrument indicates to 100 v. and has an outlet jack and volume control for use as a high-gain amplifier.—*Daven Co.*, 191 *Central Ave., Newark* 4, *N. J.*

Mention No. 338 when filling out card.

Rotary Selector Switch

New "Type 31-3" rotary selector switch is available with 1 to 6 poles up to 12 positions. Units have solid silver contacts and totally enclosed construction; contact resistance is 0.001 ohm.



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AIR VELOCITY

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SO SMALL IT FITS IN THE PALM OF YOUR HAND*

IDEAL FOR:

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- Air Conditioning
- Heating
- Inspection Work
- Gas Flowmeter
- Anywhere air or gas velocities are to be measured

The HASTINGS AIR-METER is ideal for measurement of air and gas velocities from a low of 5 feet per minute up to 6,000 feet per minute. The instrument's unique principle of operation eliminates the effect of temperature and rate of temperature change. It is not affected by normal atmospheric pressure changes. A compact unit that weighs only 24 ounces. May be operated from a 110 V, 60 cycle a-c outlet or from a battery pack.

*Adaptable to standard extension cords

ALSO THE HASTINGS PRECISION AIR-METER

Developed for field or laboratory use where extreme sensitivity and stability are required. Operates on same principle as standard Air-Meter. Easily adapted for use as a flowmeter or with remote recording or indicating instruments. Reading indicator lag is less than one second. Other special probes available. WRITE TODAY for complete data on both Air-Meters.

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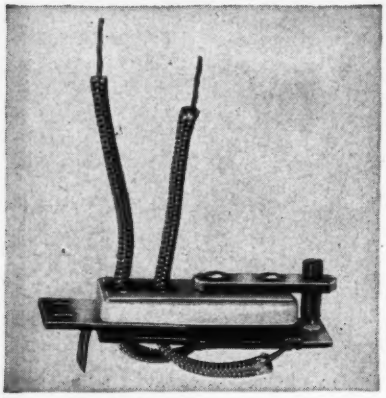
ULANET RUGGEDLY DESIGNED

Miniature THERMAL TIMERS

Provide timing ranges of 2 seconds to 3 minutes



★ These miniature units actually require a space less than 1⅜" x ⅝" x ½", yet the sturdy design contributes to long life.

A Steatite base provides dimensional stability while mounting is accomplished thru a Bakelite bracket which furnishes complete insulation as well as elimination of pressure on the ceramic member. Electrolytic silver contacts insure best conductivity and longer operation. Stable adjustment is provided for by the clinch-type bracket which holds the adjustment screw. Contact rating is 100 watts 115-230 volts ac.

Of course the Ulanet line includes many other Timing and Thermostat units. Why not investigate the vast line of miniature and sub-miniature designs available. State application or requirements when writing.

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It your problem is *Heat Control* your solution is *Ulanet*—
Precision Thermostats & Thermal Timers Exclusively Since 1931

ULANET
ELECTRIC HEAT CONTROL ENGINEERS

Maximum inductance is less than 0.03 microhenry and capacitance is less than 0.5 uuf. Contact interrupting capacity is 1 amp. at 110 v. 60 cps. on resistance load.—*Leeds & Northrup Co.*, 4934 *Stenton Ave., Philadelphia* 44, *Pa.*

Mention No. 339 when filling out card.

Engine Tachometer

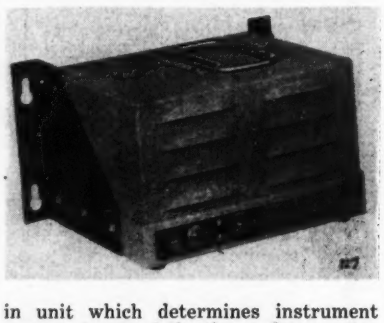
New tachometer operates from sending switch mounted on distributor of internal combustion engines; tachometer head mounts on steering post or

dash. "Standard" model shows engine speed up to 4500 rpm.; "Recorder" model also shows total revolutions; "Vac-Tach" model has a vacuum-gage in addition.—*Instrument Div., Stewart-Warner Corp.*, 1826 *Diversey Pkwy., Chicago* 14, *Ill.*

Mention No. 340 when filling out card.

D-c. Amplifier

New "Model 1411" d-c. amplifier is a degenerative feed-back type in which error-difference is converted to a.c. then amplified and rectified to d.c. to supply output. Feed-back circuit is plug-



in unit which determines instrument range. A new induction galvanometer operating at 200 kc. converts d-c. input to a.c. Unit is sensitive to input disturbances only around 200 kc.—*Weston Electrical Instrument Corp.*, 614 *Frelinghuysen Ave., Newark* 5, *N. J.*

Mention No. 341 when filling out card.

Miniature D-c. Multiple Relays

New "Frame 220" relays are supplied in "Type A" for operation at ambient temperatures up to 200 C., and "Type B" for ambients to 85 C. Up to 6-p. d-t. contacts are available in hermetically-sealed metal containers 1.25 in. diameter by 1.5 in. long and

Century
RECORDING GALVANOMETERS

The Century Model 210 Galvanometer has been designed and tested for the utmost in performance under any conditions. The unique small tubular type construction permits their installation in practically any type or make of photographic recording oscillographs. These galvanometers are offered at low cost over a wide range of frequencies and sensitivities to satisfy most recording requirements. For additional information, write for our Catalog No. CGC 206.

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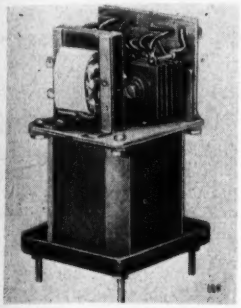
weighing only 3 oz. Units are designed to operate up to 50 g shock or 10 g vibration. Palladium contacts are rated 2 amp. at 28 v. d.c.; for expendable applications rating may be increased to 12 amp. Time of operation is less than 0.005 sec.—*Struthers-Dunn, Inc., 150 N. 13th St., Philadelphia 7, Pa.*

Mention No. 342 when filling out card.

Packaged Magnetic Amplifiers

New line of standard magnetic amplifiers operate at 60 and 400 cps. with

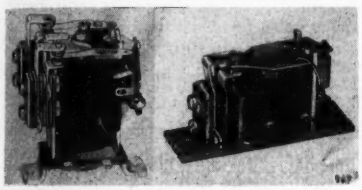


ratings to 350 watts. Units to individual specifications are also available. —*Magnetic Amplifiers, Inc., 11-54 44th Drive, Long Island City 1, N. Y.*

Mention No. 343 when filling out card.

Plate Circuit Relays

New "LM Series" relays are of long coil construction; 10,000 ohm winding pulls in at 1 ma. with contacts carrying 5 amp. Nominal operating power is 0.1 watt. Features include adjustable armature return spring and adjustable



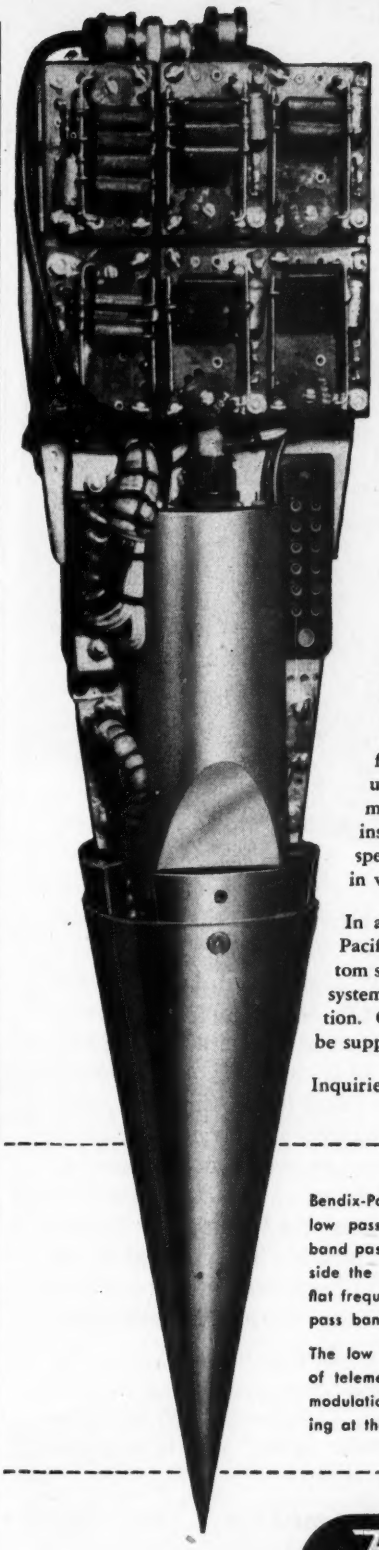
residual screw. Relays are stocked in 2500-, 5000-, and 10,000-ohm windings and all contact combinations up to d-p. d-t.

New "LS Series" are smaller and adjustments are factory set. Available in s-p.d-t. only with contacts for 5 amp. and windings of 2500 and 5000 ohms. Nominal operating power 0.2 watt and adjusted to pull in at 5 ma.—*Potter & Brumfield, Princeton, Ind.*

Mention No. 344 when filling out card.

Voltage-sensitive Relay

New "Bulletin 401" relays consist of a power type a-c. relay, with s-p. n.o. contacts and a small saturable reactor; relay coil and reactor are connected in series. Slight voltage changes across the series combination result in wide current variations required for close differential operation. Nominal coil voltages for standard heavy-duty types are 115, 230 and 440 v. 60 cps.; for light duty types 115 and 230 v. Relays



BENDIX-PACIFIC TELEMETERING EQUIPMENT PROVIDES COMPLETE INSTRUMENTATION

Bendix-Pacific standard telemetering components can be combined into a compact, highly efficient assembly to meet *exactly* your specified requirements. This extreme flexibility has been accomplished through the use of the building-block principle which permits the purchaser to assemble readily an instrumentation system exactly suited to his specific needs–thus effecting the utmost economy in volume, weight and cost.

In addition to its standard components Bendix-Pacific provides application engineering and custom system design, fabrication and test of complete systems, installation and field test and data reduction. Complete receiving station facilities can also be supplied.

Inquiries are invited.

Bendix-Pacific has recently developed new band pass and low pass filters for telemetering receiving stations. The band pass filters are characterized by high attenuation outside the pass-band by low insertion loss and by extremely flat frequency response and constant phase-shift within the pass band.

The low pass filters are designed to improve the quality of telemetering recordings through the reduction of intermodulation noise and by providing ideal electrical dampening at the input of the recording galvanometer.

Bendix Pacific Division
Bendix Aviation Corporation
NORTH HOLLYWOOD, CALIF.

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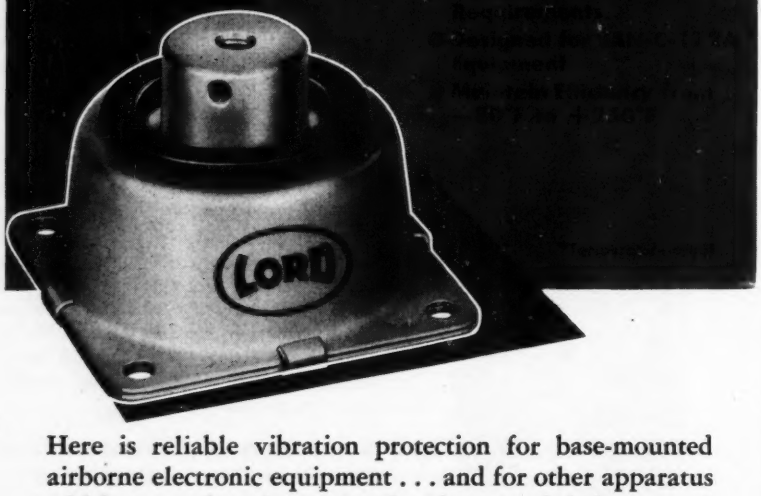
LOW-COST PROTECTION for Airborne Electronic Equipment



Here is reliable vibration protection for base-mounted airborne electronic equipment . . . and for other apparatus which must function properly above and below usual temperatures. And TEMPROOF Mountings are priced to meet the needs of manufacturers in competitive markets.

TEMPROOF Mountings provide superior protection by maintaining their high vibration-isolating efficiency from — 80°F to + 250° F. Selective-action friction dampers prevent excessive movement at resonant frequencies. Equipment does not sag or droop . . . mounting drift is negligible. The unusually wide load range of TEMPROOF Mountings makes it possible to standardize on one mounting for several types of equipment, and to effect additional economies in purchasing, storage and assembly.

For complete information on TEMPROOF Mountings, or for specific recommendations concerning their use, write to Product and Sales Engineering Department. A quantity of Vibration Isolation and Natural Frequency Charts in full color is available. Copy of each will be sent free upon request.

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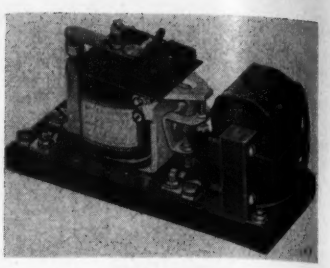
LORD BONDED RUBBER — *Vibration-Control Mountings . . . Bonded-Rubber Parts*

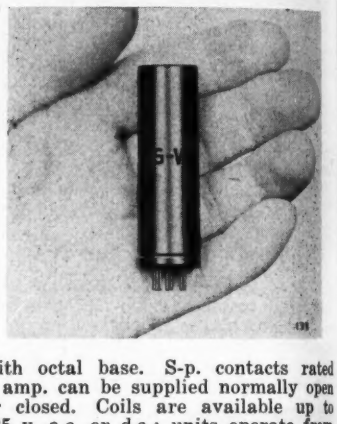


with 115-v. coils pick-up at 105 and drop-out at 95 v. Heavy-duty contacts are rated at 25 amp., 230 v. 60 cps.—*Ward Leonard Electric Co., Mount Vernon, N. Y.*

Mention No. 345 when filling out card.

Adjustable Hermetically-sealed Timing Relay

New hermetically-sealed timing relay can be adjusted over a 5:1 range; unit is available in miniature size illustrated with 7 pin base or conventional size

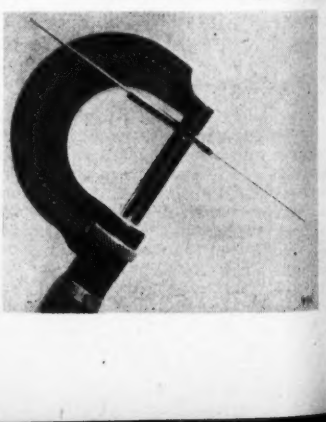


with octal base. S-p. contacts rated 6 amp. can be supplied normally open or closed. Coils are available up to 125 v. a.c. or d.c.; units operate from —70 to 125 C. Timing ranges to 3 min. can be supplied.—*G-V Controls, Inc., 28 Hollywood Plaza, East Orange, N.J.*

Mention No. 346 when filling out card.

Subminiature Selenium Rectifier

New subminiature "Microstak" selenium rectifier "smallest in the world" has an outside diameter of less than 0.0937 in. for completely-insulated or hermetically-sealed assembly. Length varies according to voltage requirements. Rectifier plates are only 0.0625 in. diam. and available for direct mounting into base of printed circuit or other unenclosed-unit usage. Units

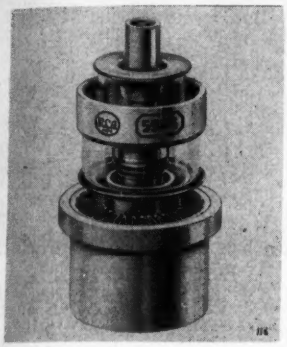


deliver 300 microamp. Longer leakage path said to reduce short circuit possibility to minimum. Units with ferrule or pigtail leads and ratings to 25 ma. available. Voltage ratings to 25,000 v. are standard.—*Hardy Instrument Co., 104-18 Metropolitan Ave., Forest Hills, N. Y.*

Mention No. 347 when filling out card.

UHF Plate-pulsed Power Triode

New "Type 5946" power triode is forced-air-cooled; maximum plate dissipation is 250 watts. In can be operated

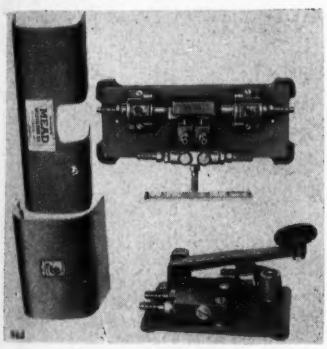


with full plate voltage up to 1300 Mc. Tube features a coaxial electrode structure, large-area RF electrode terminals, and effective isolation of plate from cathode.—*Tube Dep't, Radio Corp. of America, Harrison, N. J.*

Mention No. 348 when filling out card.

Pneumatic Timers

New "Models 4 and 5" pneumatic timers are designed to work in machine control circuits. "Model 4" will operate single- or double-acting cylinders;



"Model 5" single-acting only. Both models require pneumatic limit switches to initiate control action.—*Dep't T-37, Mead Specialties Co., 4114 N. Knox Ave., Chicago 41, Ill.*

Mention No. 349 when filling out card.

Automotive RF Interference Suppressors

New "MC Series and Type NF 10072" capacitors are hermetically sealed and operate over temperature range from −55 to 85 C. Units are non-inductively

Here may be the answer to your RECORDING problem

Sanborn Amplifier Recorders are being found outstandingly useful in a wide variety of industrial recording applications. Records are produced *directly*, and continuously, by *heated stylus* on plastic coated record paper (Permapaper), are in *true rectangular* coordinates, and are sharp, clear, and *permanent*. Elimination of the *ink flow* type of recording permits the use of these recorders in any position and at any angle. The writing arm (or arms) is driven by a D'Arsonval moving coil galvanometer with an extremely high torque movement (200,000 dyne cms per cm deflection).

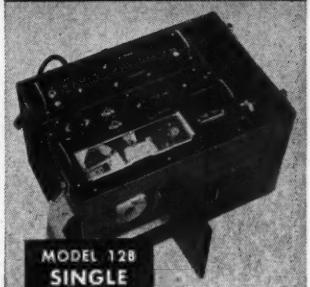
The single channel Model 128 is a vacuum tube recording voltmeter capable of reproducing electrical phenomena from the order of a few millivolts to more than 200 volts. Standard paper speed is 25 mm/sec. Slower speeds of 10, 5, and 2.5 mm/sec. are available. A variety of interchangeable amplifiers is available.

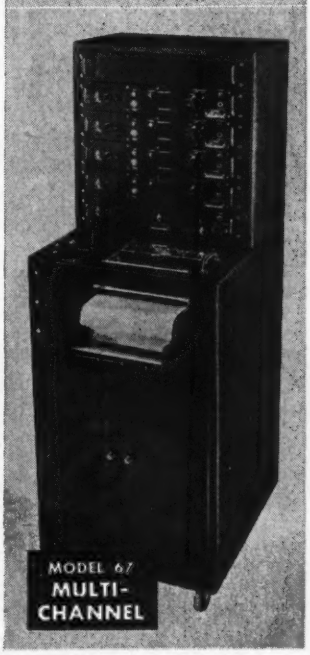
The multi-channel Model 67 provides for the simultaneous registration of *up to four* input phenomena on one record using, in a multiple system, the same principles and methods as the single channel Model 128.

In addition, this vertically mounted, metal cased amplifier-recorder provides a choice of eight paper speeds: 50, 25, 10, 5, 2.5, 1.0, 0.5 and 0.25 mm/sec., and further provides for the use of 4-, 2-, or 1-channel recording paper. Complete versatility of recording is offered in this unit by means of interchangeable amplifiers which permit the registration of stresses, strains, velocities, etc., along with the usual D.C. or A.C. phenomena.

The recorder and amplifier units of which the above models are comprised are also available separately.

SANBORN AMPLIFIER-RECORDERS





For complete catalog giving tables of constants, sizes and weights, illustrations, general description, and prices, address:

SANBORN COMPANY
Industrial Division
CAMBRIDGE 39, MASS.

Sanborn Recorders and Amplifiers have evolved from those originally designed by Sanborn Company for use in electrocardiographs, and have, by actual practice, proven to have wide applications in the industrial field as well.

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of Diamond AEMCo Quality

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"Can" Type
With Plug-in
Tube Base
A. C. or D. C.
Midget Relays
Dual Purpose
Relays
Delayed
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"Potential" Relays

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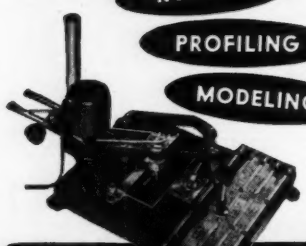

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A NEW
High Power, Lighter Weight
PORTABLE POWER UNIT

For high power from a small unit, the new Burgess A. M. Power Units are *unexcelled!* Single cell units scarcely larger than an ordinary flashlight cell deliver currents as high as 100 amperes, at approximately 1.4 volts!

New Burgess A. M. Power Unit

A. M. Units are packed dry and activated with water . . . once activated they may be efficiently discharged at temperatures as low as - 60°F. and as high as +150°F.! Write Dept. AM for full information on standard and special types.

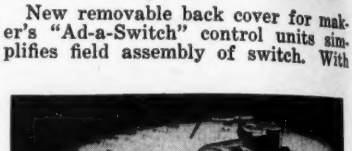
BURGESS BATTERY COMPANY FREEPORT, ILLINOIS

wound with short internal connections. "MC Series" available with three bracket styles; "Type NF 10072" has universal mounting bracket. All have terminal studs with fastener screws.—*Cornell-Dubilier Electric Corp., South Plainfield, N. J.*

Mention No. 350 when filling out card.

Removable Switch Cover

New removable back cover for maker's "Ad-a-Switch" control units simplifies field assembly of switch. With

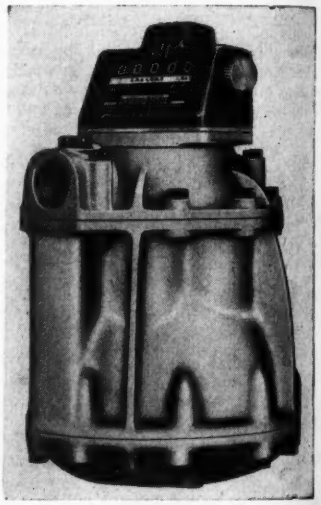


cover removed switch case is held in place by two lugs; switch mechanism and control rotor are correctly aligned. —*Clarostat Mfg. Co., Inc., Dover, N. H.*

Mention No. 351 when filling out card.

Positive Displacement Meter

New "Fig. 460-110" positive displacement meter has a capacity of 110 gpm.; body is rated 125 psi. 250 F. Interior

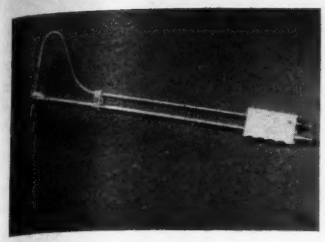


parts are stainless and hard carbon steel; exterior may be cast iron or bronze. A variety of dials are available.—*Bowser, Inc., Fort Wayne, Ind.*

Mention No. 352 when filling out card.

Remote Pipette Control

New remote pipette control can be used with pipettes ranging from 100 lambdas up to 5 ml. Unit grasps pipette and places lip in a receptor tapered for air-tight accommodation. Han-



dle has built-in hypodermic syringe normally 5 ml.; a smaller syringe with an appropriate bushing can be used.—*Nuclear Research and Development, Inc.*, 1094 *Sutter Ave., St. Louis* 5, *Mo.*

Mention No. 353 when filling out card.

Aluminum Solder Flux

New "No. 39 Brazaloy" aluminum solder flux uses water as solvent. Flux can be used with open flame or soldering iron; makes solder flow into joint, and enables soldering aluminum to other metals.—*All-State Welding Alloys Co., Inc.*, 273 *Ferris Ave., White Plains, N. Y.*

Mention No. 354 when filling out card.

Finger Chamber Radioactivity Detector

New "Model L-66" chamber mounts on finger; unit is 0.5 in. diam. 1.56 in. long. Range is 2 roentgen; instrument

measures radiation with energy from 75 kv. to 1.5 Mev.—*Landsverk Electrometer Co., c/o Technical Associates*, 3730 *San Fernando Rd., Glendale* 4, *Calif.*

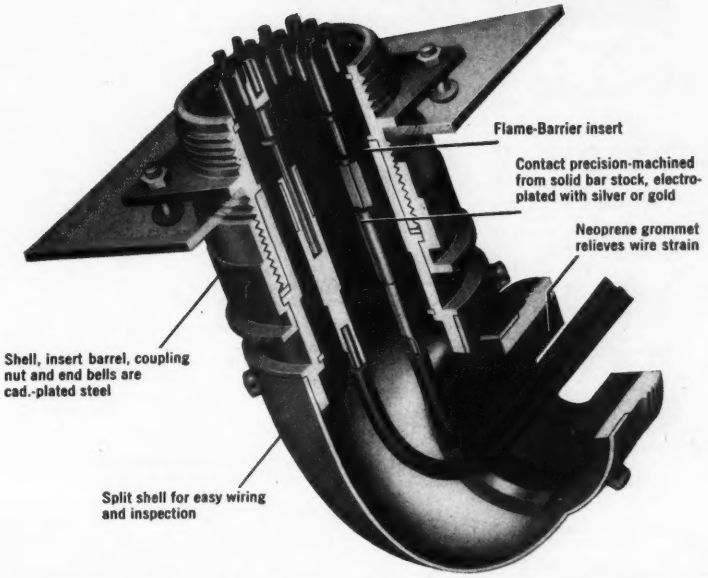
Mention No. 355 when filling out card.

Pocket Chamber Radioactivity Detector

New "Model L-65" chamber is worn in pocket. Unit is calibrated for gamma rays of cobalt 60; is sensitive to gamma-

Here's why those in the know

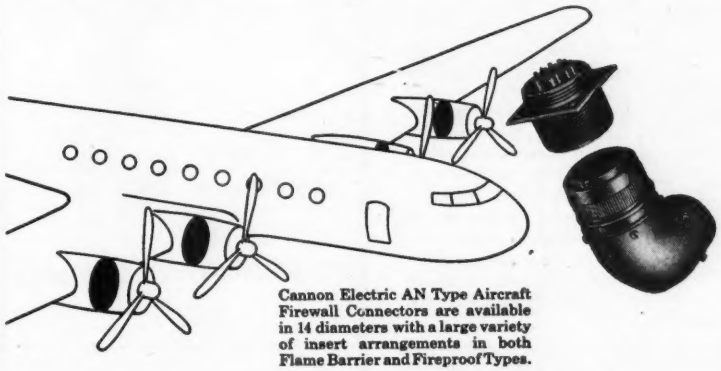
—demand **CANNON PLUGS**


Flame-Barrier insert
Contact precision-machined from solid bar stock, electro-plated with silver or gold
Neoprene grommet relieves wire strain
Shell, insert barrel, coupling nut and end bells are cad.-plated steel
Split shell for easy wiring and inspection

Here is another example of the care Cannon Electric takes in developing a connector for specialized use. This is the Firewall Connector to prevent the spread of a possible aircraft engine fire through the bulkhead into wing sections.

Illustration shows Flame Barrier type with phenolic insert and contacts having solder cups. Shell must resist an open flame of 2000° F for 20 minutes. Electric circuits not required to remain active.

The Fireproof continuous service type is similar in appearance, but has crimp-on type contacts in fireproof insert material. Must carry rated DC current under open flame of 2000° F for five minutes and withstand vibration of ¼" double amplitude at 2000 cycles per minute. Designed for aircraft, this connector has other applications where the going is tough. *For further information request Cannon Electric Firewall Bulletin.*



Cannon Electric AN Type Aircraft Firewall Connectors are available in 14 diameters with a large variety of insert arrangements in both Flame Barrier and Fireproof Types.

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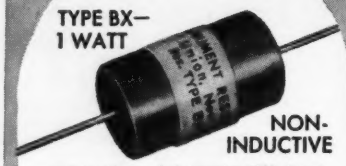
TYPE BX— 1 WATT



NON-INDUCTIVE

MAX. RES: 1.5 Megohm (331 Alloy) 1.0 Megohm (Nichrome) 30,000 Ohms (Manganin)

BODY SIZE: 1" lg. by 9/16" diam.

TOLERANCE: STANDARD 1% (TO 1/10% at Slight Extra Cost)

TYPE CX— ½ WATT

NON-INDUCTIVE

MAX. RES: 750,000 ohm (331 Alloy) 500,000 ohm (Nichrome) 15,000 ohm (Manganin)

BODY SIZE: 5/8" lg. by 9/16" diam.

TOLERANCE: STANDARD 1% (TO 1/10% at Slight Extra Cost)

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INSTRUMENT RESISTORS CO., 1036 COMMERCE AVE., UNION, N. J.

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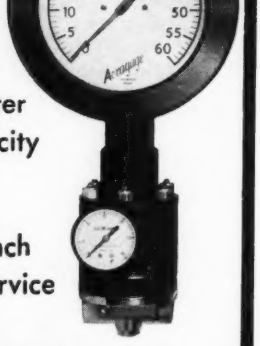
ACRAGAGE PNEUMATIC TRANSMITTER



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- A Cinch to Service

"The Solid Front Acragage and the Moore Transmitter"

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ACRAGAGE CO.

Formerly Clapp Instrument Co.

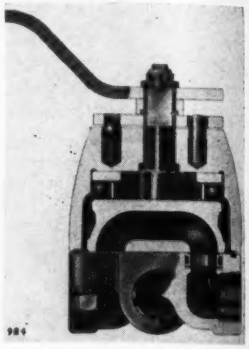
MILFORD, CONN.

and x-rays from 75 kv. to 1.5 Mev. Chamber is 0.5 in. diameter, 3.5 in. long, weighs 0.2 oz.—*Landsverk Electrometer Co., c/o Technical Associates, 3730 San Fernando Rd., Glendale 4, Calif.*

Mention No. 356 when filling out card.

Hydraulic Control Valves

New "Shear-Seal" valves have ratings to 6000 psi. Valve body is hydraulic bronze, housing is meehanite,

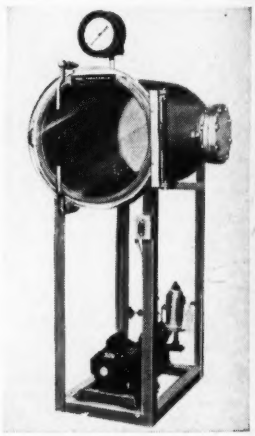


and rotor is cast steel. Valve sizes from 0.25 to 1.5 in. are available in 2-way 4-way selector and 4-way dual pressure patterns.—*Barksdale Valves, 1566 E. Slauson Ave., Los Angeles, Calif.*

Mention No. 357 when filling out card.

High-altitude Test Chamber

New high-altitude test chamber simulates conditions up to 60,000 ft. Drum head is welded construction; heavy glass circular door is flanged with seal-

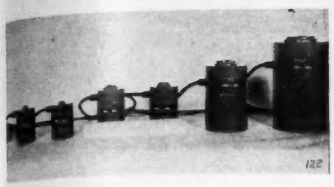


ing ring and latches for vacuum-tight fit. A 1-in. port provides for electrical leads. Chamber is available mounted with vacuum pump as illustrated, or bench mounted with remote pump.—*Tenney Engineering, Inc., 26 Ave. B, Newark 5, N. J.*

Mention No. 358 when filling out card.

Load Cells

New "U-1 Series" load cells have sealed-in SR-4 strain gages bonded to a steel column and compensated for temperature variations. Female threads on both ends of cells take tension or

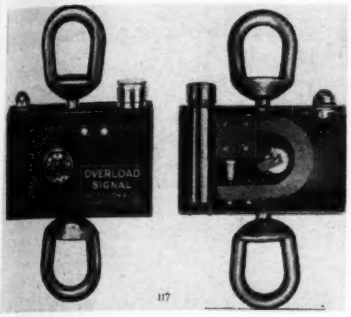


compression fittings. Load capacities range from 500 to 50,000 lbs.; overloads to 150 percent of capacity will not damage units. Accuracy is 0.25 percent of full range at any load within rated capacity.—*Baldwin-Lima-Hamilton Corp., Philadelphia 42, Pa.*

Mention No. 359 when filling out card.

Overload Warning Signal

New overload warning signal for hoists has self-contained light and bell; can be set to operate between 500 and



10,000 lbs. Over-all height 14.75 in.; weight 11.5 lbs.—*W. C. Dillon & Co., Inc., 1421 S. Circle Ave., Forest Park (Chicago), Ill.*

Mention No. 360 when filling out card.

Low-voltage Test Light

New "Model 1300" test light is encased in plastic housing; has 10-in. flexible leads terminated in spring clips.

Bulb lights on 3 to 25 v. "Model 1310" is similar but lights on 6 to 50 v.—*Industrial Devices, Inc., Edgewater, N. J.*

Mention No. 361 when filling out card.

Armored Conductivity Cells

New armored conductivity cells for measurement of strong sulfuric acid concentrations are supplied in pairs with one cell as reference and other as measuring cell. Pressure seal has been redesigned to eliminate dependence upon glass parts. Designed for pipe line installations, cells are suitable for line pressures to 50 psi. Units are made of heavy wall pyrex with platinum elec-

TO CHECK RELATIVE HUMIDITY REMEMBER

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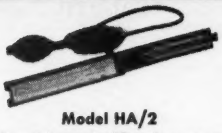
Model 185 Hygrodial
Precision Humidity and Temperature Indicator
Hair-operated and calibrated to professional standards of accuracy by the maker of the world's finest weather instruments. Handsome, modern case—4" high, 5½" wide, 1⅝" deep.



Model HA/2
Hand Aspirated Psychrometer
Accurate readings obtainable without special skill. Psychrometric readings can be taken at any point desired however inaccessible.

Model 160
Portable Humidity and Temperature Recorder
3" x 5" charts, 10 or 30 hour records. Modern design...handy for small space and difficult locations . . . built to meet unusual conditions.

Model 594
Hygrothermograph
The foremost relative humidity recorder for laboratory, factory, and office use. Scientifically designed for accuracy and dependability.

Model 573
Motor Aspirated Psychrometer
Designed to determine wet and dry bulb temperature with laboratory accuracy—Motors supplied for use on 115 V., 50 cycles or 60 cycles.

Model S/1
Pocket Sling Psychrometer
A small, low cost instrument. Thermometers graduated in 1° increments from +35° F to +110° F. Furnished complete with case and psychometric slide rule.

Model 550
Sling Psychrometer
Manufactured to U. S. Weather bureau specifications. Thermometers graduated in 1° increments from −20° F to +120° F. or −35° C to +49° C.

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CHECK small inductors

...Quickly and Accurately—

with this TYPE 110-B

QX-CHECKER

The QX-Checker is a production type test instrument specifically designed to compare the reactance and relative Q of small RF inductors with approved standards. The two factors, reactance and relative Q, are separately indicated, one on the meter and the other on a condenser dial, so that the deviation of either from established tolerances is immediately shown. Built to laboratory standards, the QX-Checker is a sturdy, foolproof instrument for use in production work by factory personnel.

SPECIFICATIONS

OSCILLATOR FREQUENCY RANGE: 1.5 to 25 mc. in 3 ranges using accessory plug-in-coils (two coils furnished with each instrument).

ACCURACY OF COIL CHECKS: Inductance values between 5 and 35 microhenries may be checked to an accuracy of ±0.5%. Smaller values down to 0.1 microhenries may be checked with decreasing accuracy.

INDICATING SYSTEM: Q indicating meter with well expanded 3¼" scale shows departure of Q from nominal value. Vernier condenser scale calibrated directly in terms of percent departure from known standard over range of −15% to +20%. Capacitance scale is also provided reading changes of −50 mmf. to +50 mmf. from nominal circuit capacitance of 300 mmf.

POWER SUPPLY: 110-125 volts, 50-60 cycles, also 200-250 volts, 50 cycles.

DIMENSIONS: Width 12¼", Depth 18", Height 8".

WEIGHT: 26 lbs. PRICE: $415.00 f.o.b. Boonton, N. J.

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BOONTON RADIO Corporation
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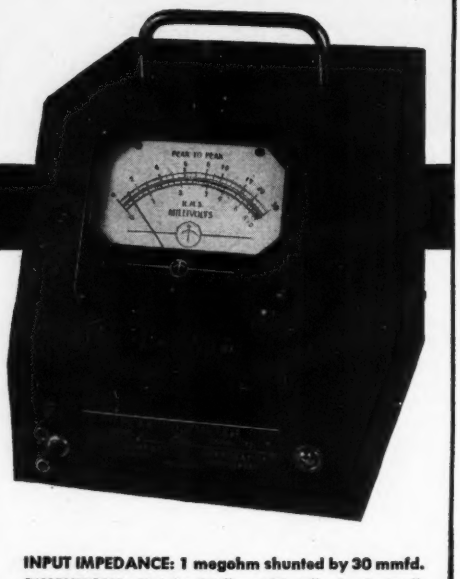
DESIGNERS AND MANUFACTURERS OF THE "Q METER . . . QX-CHECKER . . . FREQUENCY MODULATED SIGNAL GENERATOR . . . BEAT FREQUENCY GENERATOR . . . AND OTHER DIRECT READING TEST INSTRUMENTS

MEASUREMENTS CORPORATION

Peak-to-Peak VOLTMETER

.0005—300 VOLTS



MODEL 67

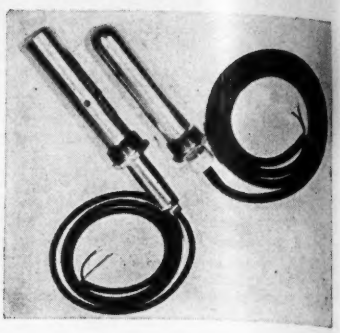
Designed for accurate indication of the peak-to-peak values of symmetrical and asymmetrical waveforms, varying from low frequency square waves to pulses of less than five microseconds duration.

.0005-300 volts peak-to-peak, .0002-100 volts r.m.s. in five ranges. Semi-logarithmic, hand calibrated scales.

Provision for connection to 1500 ohm, 1 milliampere graphic recorder or milliammeter.

INPUT IMPEDANCE: 1 megohm shunted by 30 mmfd.
DIMENSIONS: Height 7½", width 7", depth 8½". Weight 8 lbs.
POWER SUPPLY: 117 volts, 50-60 cycles, 35 watts.

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

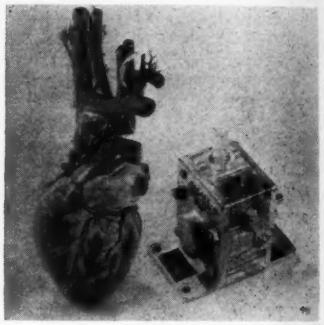


trodes and matched cell constants of 1.00. Metal parts are of either steel or type 316 stainless steel.—*Industrial Instruments, Inc.*, 17 *Pollock Ave., Jersey City* 5, *N. J.*

Mention No. 362 when filling out card.

Positive-displacement Pump

New "Flex-i-liner" pump application is in heart-lung device. Eccentric rotor mounted on a ball bearing activates flexible plastic liner against inner surface of body block. Capacities range to 5 gpm. Variety of corrosion-resistant materials available. Over-all size of pump is 3.75 x 1.5 x 2.5 in.—*Vanton Pump Corp., Empire State Bldg., New York, N. Y.*



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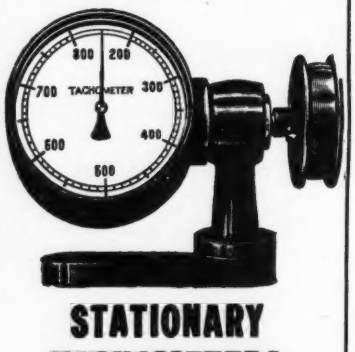

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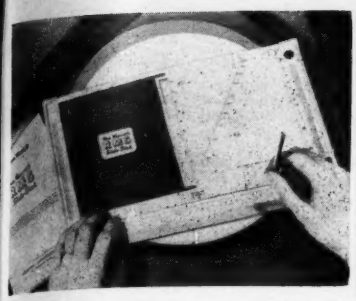
New "RMS Slide-Disk" consists of 10-in. disk that slides and rotates under a pair of vertical and horizontal scales on which right triangles are formed graphically. Operations of squaring, summing squares, and square-rooting required in statistical computations are performed simultaneously. Units are



furnished with linear and logarithmic scales; are accurate to 0.5 percent.—*Graphic Calculator Co.*, 633 *Plymouth Court, Chicago* 5, *Ill.*

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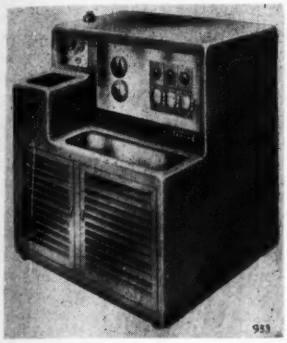
Hot-cold Test Stand

New hot-cold test stand produces temperatures from −70 to 230 F. Work chamber accommodates parts up to 6 x 6 x 8 in. Temperature-controlled fluid can be circulated in a closed system a



short distance from test stand in insulated lines. Unit is self-contained and requires only power and water supply; over-all dimensions 30 x 40 x 54 in.—*Electro Mechanical Devices Div., George L. Nankervis Co.*, 19255 *W. Davison, Detroit* 23, *Mich.*

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New improved weight indicator has 16-in. diameter dial; graduated scale is 47 in. long. Load ranges from 250 to 20,000 lb. available with tare load compensation features standard. Mechanism consists of calibrated beam whose

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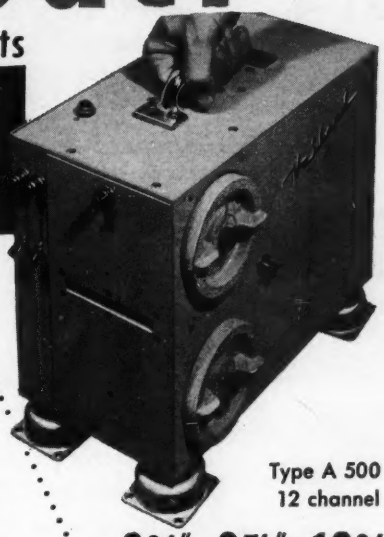

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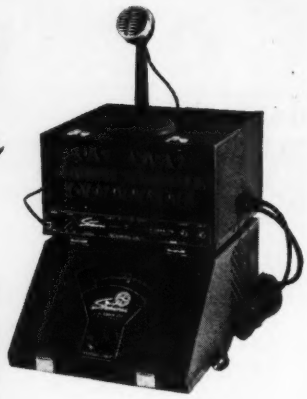

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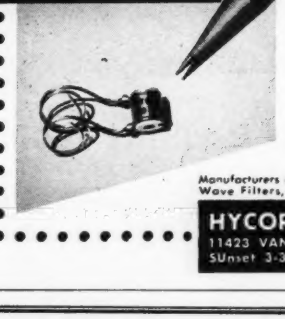

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deflection is measure of load applied.—*W. C. Dillon & Co., Inc.*, 1421 *S. Circle Ave., Forest Park (Suburb of Chicago), Ill.*

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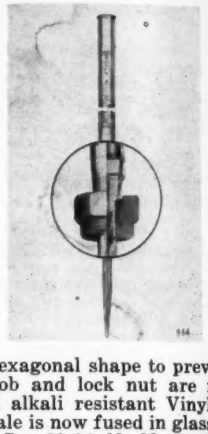
New improved "Ultramax" burette has Teflon plug to give positive turning and independent adjustment of pressure. Round knob has been replaced



with a hexagonal shape to prevent rolling. Knob and lock nut are made of acid and alkali resistant Vinylite. Ceramic scale is now fused in glass.—*Emil Greiner Co.*, 20-26 *N. Moore St., New York* 13, *N. Y.*

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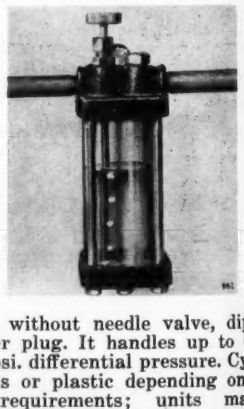
Sight Feed Bubbler and Sediment Trap

New sight feed bubbler passes flow of gas or air through liquid in a transparent cylinder. Needle valve permits adjustment of flow from 1 bubble per sec. to 20 cfh. Sediment trap is similar



except without needle valve, dip tube or filler plug. It handles up to 6 cfm. at 25 psi. differential pressure. Cylinder is glass or plastic depending on pressure requirements; units may be mounted on front of panel or in gas line.—*King Engineering Corp., Box* 500, *Ann Arbor, Mich.*

Mention No. 369 when filling out card.

Conductive Coating

New conductive coating is used for recoating outside of TV picture tubes at scratched and peeled spots; also used on inside of TV cabinets to prevent high-voltage leakage and discharges.—*General Cement Mfg. Co., Rockford, Ill.*

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NOVEL MEASURING METHOD

Continued from page 286

during the first period and

$$V_2 = U \log (I_1 + I_2) - U \log I_0 \quad (4)$$

during the second period. The difference between these two voltages is

$$V_2 - V_1 = U \log (I_1 + I_2) - U \log I_1$$
$$= U \log (I_1 + I_2) / I_1$$
$$= U \log (I_2/I_1 + 1) \quad (5)$$

Thus the *difference* between the voltages in the two periods is a measure of the *proportion* between the photo-current due to the interrupted light through cell C2 and the uninterrupted light through cell C1.

The voltage on the grid will alternate at the rate of the interruptions of the light through cell C2 between the values of V_1 and V_2, producing between grid and cathode an alternating voltage of the peak to peak amplitude of $V_2 - V_1$. This alternating voltage can be amplified and measured by well-known methods.

Thus the entire proportioning gear consists of merely connecting the cathode of the sensing element (phototube) to the first grid of an amplifier tube, insulating this grid from all other circuit elements, and determining the amplitude of alternating voltage appearing on the grid. Then, as is seen from Eq. (5), the reading is a measure of the *proportion* between the current corresponding to the magnitude to be determined and the current corresponding to the standard magnitude.

The same principle may also be applied to determine the proportion between two magnitudes both of which are variable. An example is the determination of suspended impurities in transparent liquids. If a beam of light is thrown through a liquid, suspended particles cause a portion of this light to deviate from its original direction. The proportion between the light thus deviated and light proceeding in its original direction is a measure of the amount of impurities present. A simplified scheme of one practical embodiment* of this new method is given in Fig. 2. The fluid to be tested fills the inspection chamber C. An incandescent lamp and a first lens L1 throw a substantially parallel beam of light through it. A second lens L2 forms an image of the filament in its focal plane and thus concentrates the undeviated rays over a small area. The deviated rays are scattered around this area. The large condensing lens L3 directs both the scattered rays and the unscattered rays to the same phototube P. But while the rays scattered over the clear area of the lens L3 are allowed to reach the phototube without interruption, the rotating glass disk D, carrying dark and transparent areas, periodically interrupts the passage of the non-scattered rays. The photocurrent is sent through the grid to cathode path of a vacuum tube and the alternating voltage across this path is amplified and measured. The output signal is a measure of the proportion

*Continuous Industrial Nephelometer "Purifil" produced by Electric Eye Equipment Co., Danville, Ill.

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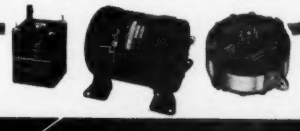

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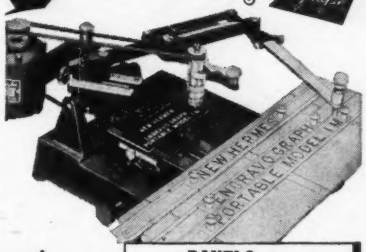

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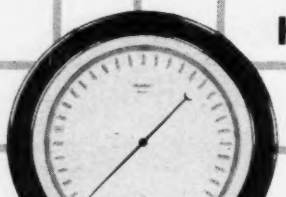

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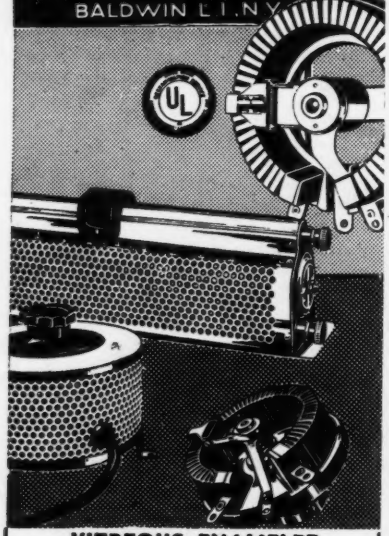

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between scattered and non-scattered rays and hence of the concentration of the suspended particles. As the arrangement measures the *proportion* between scattered and non-scattered rays, it is independent of absorption of light inside the fluid or of aging of the lamp being used. As this proportion is being measured by the proportion between photocurrents transmitted by the same phototube, its value is obtained accurately and independently from drift in the sensitivity of this phototube. As measurement of the proportion is being accomplished by the logarithmic relationship between grid current and grid voltage, no mechanical proportioning gear is needed.

Other applications of the principle are in various stages of development and still others may come along in connection with new requirements of industry, or new sensing elements which may require independence from shifting sensitivity.

HIGH VACUUM EVAPORATION

Continued from page 285

pattern over a surface of practically any radius. Even such techniques do not preclude the chance of non-uniform deposits, but such non-uniformity as might result from unpredictable focusing or directional effects of the source can be controlled to such an extent as to keep the film thickness uniform to a degree that will confine the corresponding wavelength maxima transmitted to a region close to the optimum. In practice, these techniques are seldom required, but they serve to illustrate the means available to control the density of molecular vapors in vacuum and thereby correct or vary the thickness of the deposited films.

The problem of producing uniform mirror surfaces is similar but not so acute. In the case of mirrors, the light is not required to traverse the film of metal and, therefore, reasonable variations in the thickness of an opaque film cannot effect the nature of the reflected light. Although the nature of the reflected light is not reflected, it is conceivable that the "figure" of the reflecting surface could be altered. This alteration of the "figure" by an evaporated film was accomplished by John Strong using a rotating baffle as previously described.

Spherical mirrors have been parobolized using these techniques; but little advantage is gained in practice since the whole laborious process must be repeated at each aluminizing.

A question at this point might be: How much "de-figuring" is introduced during the normal operation of aluminizing and overcoating a mirror? The obvious answer is that the thinner the films deposited the less is the risk of developing a non-uniform thickness which could effectively change the figure. This risk diminishes of course as the source of the mirroring metal is located close to the center of curvature of the surface. This is rarely possible, hence the previous option is adopted and the evaporation of the metal is stopped

as soon as the most distant parts of the surface reach opacity. Even where the geometry during evaporation is such that some portions of the surface acquire twice as much as the minimum for opacity, this is still such a small departure from the ideal surface that the few hundred Angstroms difference would scarcely be detected in terms of a test or performance.

The previous considerations are based on plain aluminizing without any protective overcoating except what aluminum may oxidize to aluminum oxide. The development of silicon monoxide protective coatings provides the high vacuum coater with a new tool which will serve well when used with discretion.

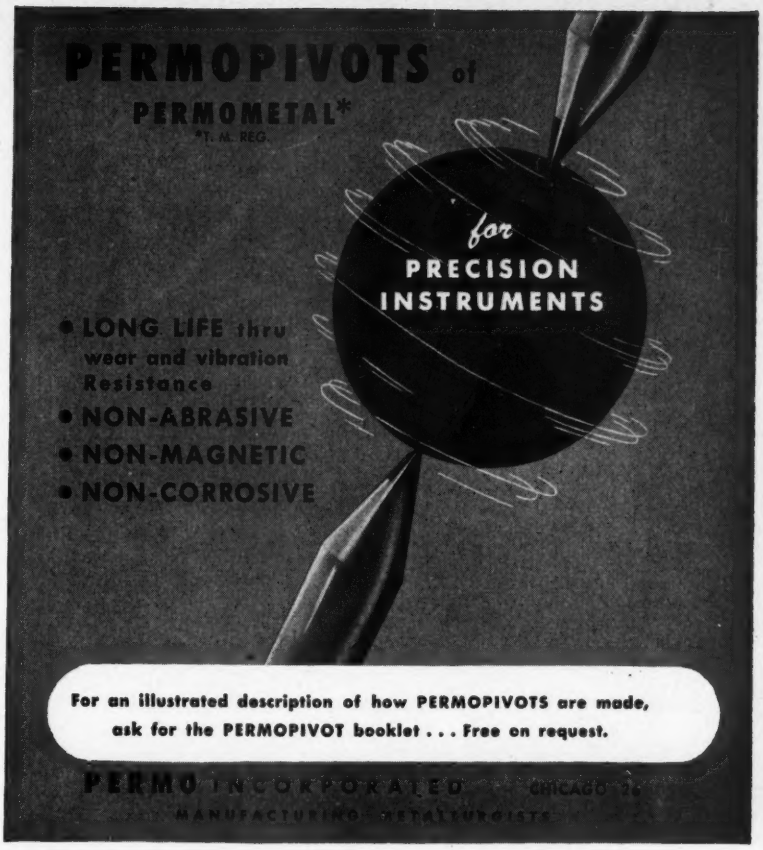
Here too, however, the problem of developing uniform films is also a factor, though not in the sense that they may alter the reflecting surface. The problem seems to be one of depositing a film which will give a reasonable measure of protection and still not be so thick as to introduce optical path differences which would have a differential phasing effect on marginal and axial rays.

Little information on such phenomena is available and until some better system is propounded, the best defense is to keep such protective coatings well below one-fourth wavelength in thickness.

With so much talk about mirrors and lenses a few words on the much discussed subject of cleaning their surfaces may be in order. Let us proceed from the assumption that we can get a piece of bare glass reasonably clean. The same principles apply in cleaning glass coated with magnesium fluoride, but one special property of fluoride films must be taken into account. That property is their persistent affinity for contamination—especially, oils. Anyone who has tried to remove an oily spot from a coated lens recognizes that long after the immediate spot is removed, a slight variation in color persists over a considerable area surrounding the original location of the spot. Even after the uniform basic color of the coating is restored by using a suitable solvent to remove the contamination, it is safe to say that at least a molecular layer of oil still persists though it is much too thin to affect a change in color.

Actually this absorbed film, of insignificant thickness, is a considerable asset since it acts as an effective lubricant and barrier against scratches and abrasions which might rupture an uncoated surface. Although time honored "nose-grease" is fully equal to the task, the new family of Silicone oils possesses all the desirable properties. These oils when dispersed in a suitable vehicle can be applied to freshly coated surfaces with lasting effectiveness due to their negligible rate of evaporation.

Mirror surfaces which have been overcoated, and to a lesser degree plain aluminizing respond to the same treatment with such stable oils. Precautions must be exercised since even protected



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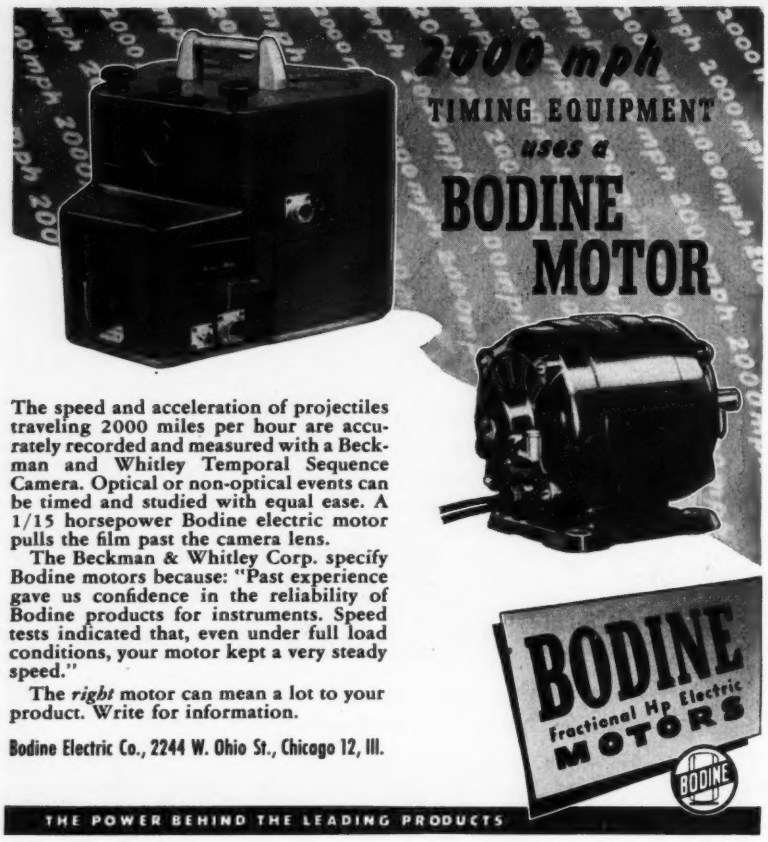

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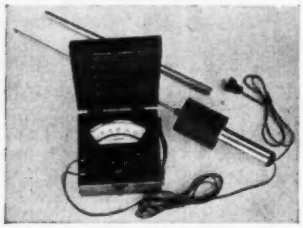

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It would seem then, that the art of high vacuum evaporation is still young. Perhaps the next few years will bring forth developments of as great influence on the science of optics as developments of the past.

HEAT—HUMIDITY

Continued from page 283

non. From this review, also, it should be clear that new methods of measurement are urgently needed. Though we have seemed to pass over new devices, most of which have not yet been adequately developed for industrial uses, there is still reasonable expectancy that future progress will simplify and improve the old methods or replace them with new ones in order to extend the application of humidity measurement and control to wider fields of industrial processes.

REFERENCES

(1) W. H. Carrier, *Transactions American Society of Mechanical Engineers*, Vol. 23, 1911, page 1005.
(2) W. K. Lewis, *Transactions American Society of Mechanical Engineers*, Vol. 44, 1922, page 325.
(3) J. G. Arnold, *Physics*, Vol. 4, July 1933, page 255; ibid, Sept. 1933, page 334.
(4) D. Dropkin, *Bulletin Cornell University Engineering Experiment Station*, No. 23, 1936; ibid, No. 26, 1939.

BOOKS RECEIVED

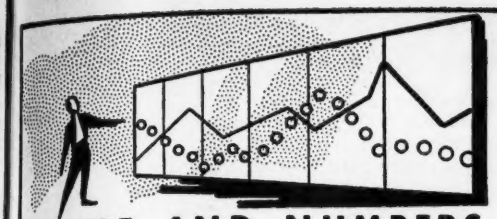
ELECTRONIC ENGINEERING MASTER INDEX 1949. Electronics Research Publishing Co., Inc., New York, 1950. Cloth, 6⅞" x 9¾". Price $17.50. A subject index to the contents of electronic and allied engineering publications printed throughout the world from January through December, 1949. Contains 12,500 references from over 400 world-wide publications, U. S., Canadian and British declassified documents, and U. S. patents. Over 600 subject headings. Cumulative subject cross index covering 1925-45, 1946, 1947-48 and 1949 editions also included.

PHYSICS IN CHEMICAL INDUSTRY. Dr. R. C. L. Bosworth. Macmillan, New York, 1950. Cloth, 6 x 9 inches, xix + 928 pages. Price $12.75. Book provides in summary form an account of the mathematics, mechanics, properties of matter, thermodynamics, kinetic theory and other aspects of applied physics as these subjects are required in chemical industry. Work includes material useful to the industrial chemist and the chemical engineer.

TECHNICAL OPTICS—Vol. II. L. C. Martin. Pitman Publishing Corp., New York, 1950. Cloth, 5½ x 8½ inches, 344 pages. Price $7.50. Deals with the magnification produced by lenses, the simple microscope, telescope, binocular vision and binocular instruments, photographic lenses, photometry of optical systems and the projection of images; the testing of optical instruments and the study of their performance, aspheric surfaces of revolution. Book is of value to scientific instrument makers, ophthalmic opticians, spectacle makers and students.

CHEMICAL ENGINEERING CATALOG. 35th Edition 1950-51. Reinhold Publishing Corp., New York, 1950. Cloth, 8½ x 11 inches, 1680 pages, price not given. A collected source of condensed and standardized data about equipment, machinery, raw materials, heavy and fine chemicals used in the industries employing chemical processes of manufacture with classified indices of such equipment and materials, carefully cross-referenced.

A.S.M.E. MECHANICAL CATALOG AND DIRECTORY—1951—40th Volume. American Society of Mechanical Engineers, New York, 1950. 645 pages. Distributed to members. Contains catalogs of industrial products, buying directory and list of trade names.



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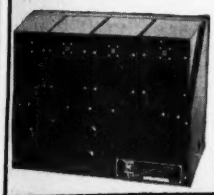

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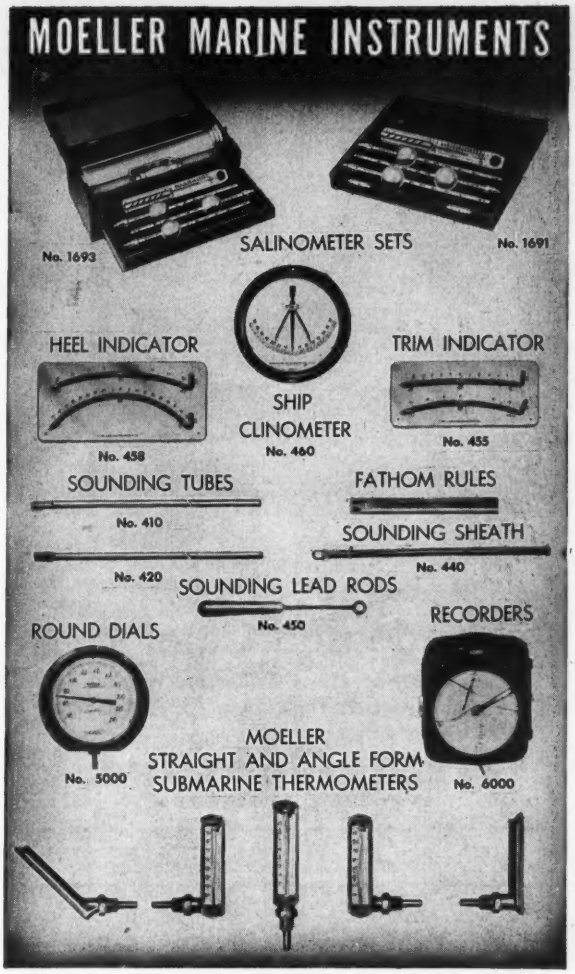

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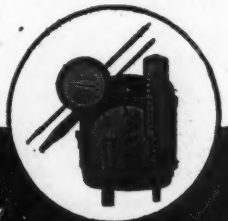

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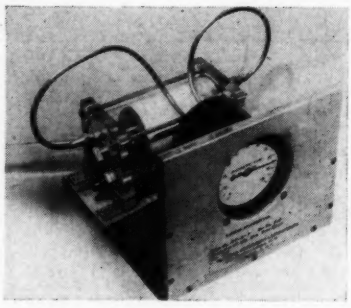

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[COVER PICTURE FEATURE]

This month's cover shows Mason-Neilan control valves operating in the gas dehydrator manifold at Magnolia Petroleum Company's Chitwood Gasoline Plant at Chitwood, Oklahoma. The valves control gas flow and regeneration of each dehydrator tower. One-quarter-inch aluminum tubing, interconnecting from instrument control panels, is utilized on the pneumatic system to these valves. Figs. 1 and 2 show additional applications of aluminum tubing on instrument pneumatic lines.

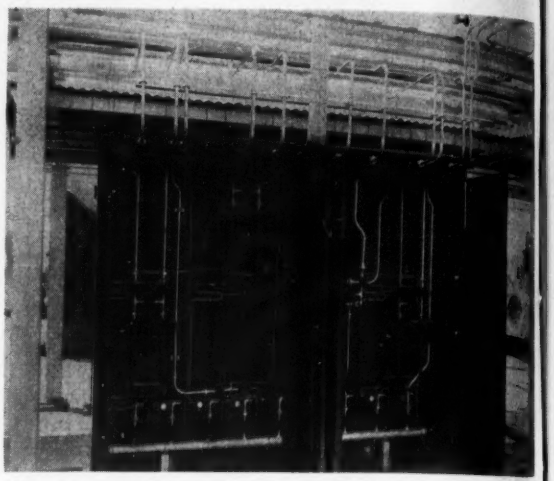

Fig. 1. Instrument control panels on fractionating columns of the Chitwood plant. Aluminum tubing is used on these Taylor instruments which control temperature, pressure, and rate of flow.

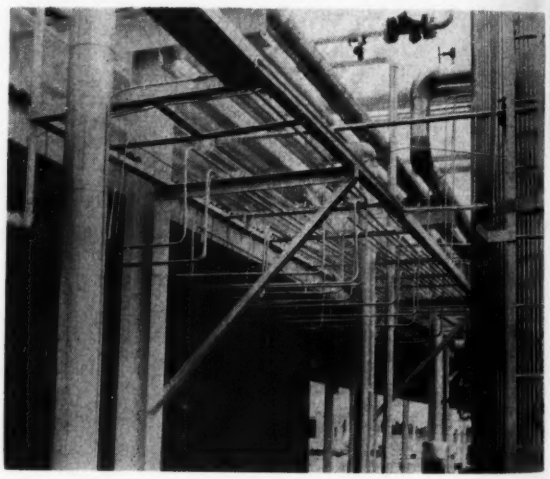

Fig. 2. Steel and aluminum instrument piping to and from one of the control panels at Sholem Alechem Gasoline Plant, in Oklahoma, operated by Magnolia Petroleum Company.

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THE SECRETARY'S PAGE

Your Employer and the Houston Meeting

There are many Society members who are keenly interested in instrumentation in its various phases but who may not, on their own, be in a position to decide to take the time off to attend the coming Instrument Conference and Exhibit in Houston, Texas, September 10-14, 1951.

To help make it possible for you to visit the "Show" and to attend the various technical discussions, it is the intention of the National Office to extend invitations to the Conference to various key executives in companies that are interested in instrumentation.

The key men in mind are those of supervisory capacity who have the authority to extend time off to personnel working with instruments. By bringing to the attention of these men the occasion of the Conference and Exhibit, and all that it covers, we may be able to stimulate their interest sufficiently for them to deem it a valuable experience for their personnel.

A copy of the invitation letter is reproduced below. If a member wishes this letter sent to the president of his company and/or to his immediate superiors he is urged to write the National Office.

Dear Sir:

You are cordially invited and requested to attend the Instrument Conference and Exhibit to be held in Houston, Texas, September 10-14, 1951, and we hope to be honored with your presence.

Although the day of the completely automatic factory is still to arrive, there is a marked movement in that direction. This trend is particularly noticeable in the chemical and petroleum industries. The basic metals, utilities, foods, textiles and ceramic industries are other fields making increased use of industrial instrumentation to lower costs and improve products.

The Sixth National Instrument Conference and Exhibit is designed to acquaint you with the latest advances in instruments and devices for measurement, inspection, testing and control. Hundreds of instruments will be shown in operation, offering an opportunity of actually seeing the progress made in the past few years.

You are urged to have those in your organization, who are responsible for the specification, installation and maintenance of instruments and controls, attend the Conference and Exhibit to see and learn of the latest developments which might be applicable to your manufacture.

Please plan to attend yourself—but by all means have your company adequately represented. You will find that it will pay worthwhile dividends in knowledge gained and prove to be time well spent.

Very truly yours,
Richard Rimbach,
Executive Secretary

P.S. Be sure to plan to send your instrument mechanics to the Pre Conference Instrument Maintenance Clinic.

Section Secretaries, Meeting Data and Programs

AKRON
Fred Appel, 932 Columbia Ct., Barberton, Ohio. Tel: SH 3440
Fourth Tuesday, 7:30 P. M., Akron Y.W.C.A.

ALBUQUERQUE
E. J. Burda, Sandia Corp., P. O. Box 5800, Albuquerque, N. Mex. Tel: 5-5511
First Monday, Meeting at 8:00 P.M., Science Lecture Hall, Univ. of N. M.

ARUBA
E. H. Pfeffer, P.O. Box 291, c/o Lago Oil & Transport Co., Ltd., Aruba, N.W.I.
First Tuesday, 7:15 P. M., Engr's Club.

ATLANTA
D. M. McRae, 150 Nassau St., Atlanta, Ga.
Fourth Monday, Meeting at 7:45 P.M., Ga Institute of Technology.

BALTIMORE
W. A. Dickinson, 2716 Dunbrook Ct., Baltimore 22, Md. Tel. Dundalk 2272J
Second Friday, Meeting at 8:00 P.M., Engr's. Club of Baltimore.
April 13, "Principles of Automatic Control," ISA Color-sound film by G. F. Atkins, J. Kowalski, Kodak Co.

BATON ROUGE
John Q. Bass, 1517 Longwood Dr., Baton Rouge, La. Tel: 3-0283
Meeting monthly, L.S.U. Physics Bldg.

BOSTON
Stephen E. Lord, 60 Braintree Ave., Quincy 69, Mass. Tel: MA 9-1066
Last Wednesday, Dinner at 6:30 P. M., Meeting at 7:00 P.M., 99 Club, 99 State St.

CALIFORNIA
D. C. Duncan, Helipot Corp., 916 Meridian Ave., S. Pasadena, Calif. Tel: SY 4-8439
Second Wednesday, Dinner at 6:30 P. M. Meeting at 8:00 P.M., Carolina Dines.

CENTRAL ILLINOIS
Thomas A. Carroll, 721 Hurlburt St., Peoria 6, Ill. Tel.: Peoria 4-8909
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M.
April 4, "Atomic and Solar Energy," L. R. Rothsteine, Ph.D.
May 2, Presidents night.

CENTRAL INDIANA
Richard F. Rieman, 3550 Euclid St., Indianapolis, Ind. Tel. CH 7462
First Tuesday, Meeting at 7:30 P. M.

CENTRAL NEW YORK
Karl W. Robertson, Minneapolis-Honeywell Reg. Co., 121 Onondaga St., Syracuse.

CHARLESTON
Fred Gilmer, 415 Bibby St., Charleston, W. Va.
First Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Kanawha Hotel
April 2, "Design of Electrical Systems for Measurement and Control," C. L. Saunders, Wheelco Inst. Co.
May 7, "Stump the Experts" program.

CHICAGO
Floyd E. Ertsman, Rm. 1420 Fisher Bldg., 343 S. Dearborn St., Chicago 4, Ill. Tel: WE 9-0686
First Monday, Dinner at 6:30 P. M., Meeting at 8:00 P. M., Shoreland Hotel.
April 2, "Unattended Booster Station on Pipe Lines," J. P. Heddin, Standard Oil Pipe Line Div. Regional Joint Meeting with Northern Indiana Section.

CHINA LAKE
A. H. Staud, 1004 Michelson Lab., USNOTS, China Lake, Calif. Tel: 77882
Fourth Thursday, Meeting at 8:00 P.M., Michelson Lab, USNOTS.

CINCINNATI
L. W. Greene, 181 Market St., Aurora, Ind.
Second Monday, 8:00 P. M., Eng'r. Society Hqs.

CLEVELAND
A. E. Ehrke, 5805 Euclid Ave., Cleveland, Ohio. Tel: Ex 1-5454
Fourth Wednesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Cleveland Eng'r. Society, E. 19th St.
March 28, "Quality Control of the Product," C. F. Fischer, G. E. Co. Cons. Lab.

COLUMBUS
W. C. Myers, c/o Battelle Memorial Institute, 505 King Ave., Columbus, Ohio. Tel: UN 3191, Ex. 248
Third Thursday, Meeting at 8:00 P.M., Battelle Auditorium

CUMBERLAND
Clyde Babst, 225 Cecilia St., Cumberland, Md. Tel: 583-W
Tuesday after Fourth Monday, 8:00 P. M., Dinner at 6:30 P. M., Algonquin Hotel.

DETROIT
A. W. Brueckner, 5556 S. Clarendon Ave., Detroit 4, Mich. Tel: TYler 6-9511.
Third Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Rackham Bldg.
April 17, "Recent Developments in Cathode Ray Oscilloscopes," S. Sterling, S. Sterling Co.
May 15, "Automatic Indication in Quality Control," T. S. Cawthorne, T. S. Cawthorne Co. Joint meeting with AIEE.

EASTERN NEW YORK
W. R. McKegg, c/o Gen. Engrg. & Consulting Lab., G. E. Co., Schenectady, N. Y.
First Tuesday, 8:00 P.M., Dinner at 6:30 P.M.

GULF COAST
W. N. Sloan, E. I. Du Pont de Nemours & Co., Orange, Texas. Tel: 8411 Ext. 444
Third Tuesday. Meeting at 7:30 P.M., Lamar College, Beaumont, Texas.

HOUSTON
I. K. Farley, 2123 Travis St., Houston, Texas, Tel: Charter 2511.
Last Monday, 8:00 P. M., Engineers Club.

KANSAS CITY
H. H. Schmall, 3706 Benton Blvd., Kansas City 3, Mo. Tel: AR 4808
First Tuesday, 7:30 P.M., U. of Kansas City.
April 3, "High Pressure Instrumentation," C. E. Balcerzak, Bur. Mines, Louisiana, Mo.
May 1, "Principles of Automatic Control," ISA Color-sound film by G. F. Akins, J. Kowalski, Kodak Co. Also tour, lecture on "Gage Laboratory," Place: Midwest Research Institute.

LOUISVILLE
C. M. Bosworth, 203 Arbor Park, N., Lo., Ky.
Fourth Tuesday, Meeting at 8:00 P.M., Seagram Auditorium.

MONTREAL
S. J. Mizuhara, 1075 Allard, Verdun, Quebec, Canada. Tel: TR 3252
Last Monday, 8:00 P. M., Mechanics' Institute.

NEW JERSEY
Fred L. Crabbe, Malcolm W. Black & Co., Inc., 41 East 42nd St., New York 17, N. Y. Tel: Vanderbilt 6-2960.
First Tuesday, Dinner at 6:00 P. M. Meeting at 8:00 P.M., Essex House, Newark.
April 3, "Panel Board Design," Symposium beginning with luncheon at noon, and resumed in the evening. Essex House Hotel.
May 1, "An Improved Pneumatic Control System," R. E. Clarridge, Taylor Inst. Co.

NEW ORLEANS
W. H. Haney, 2927 Music St., N. O. 22, La.
No Regular Date, Meeting at 8:00 P.M.

NEW YORK
F. B. Leslie, 8856 Commonwealth Blvd., Bellerose 6, N. Y. Tel: FI 7-0645
Last Monday, Dinner at 6:00 P.M., Meeting at 7:45 P. M., Hob Nob Club, 108 E. 41st St.
March 26, "Principles of Automatic Control," ISA Color-sound film by G. F. Akins, J. Kowalski, Kodak Co.

NIAGARA FRONTIER
Mrs. James L. Martin, 697 Potomac Ave., Buffalo 22, N. Y. Tel: GR 1450
Fourth Monday, Dinner at 6:00 P.M., Meeting at 8:00 P.M., N. Y. State Inst. of Arts and Sciences, Buffalo.
March 26, H. W. Barrett, Buffalo Meter Co.
April 23, "Air Operated Controls," J. A. Pellettere, Gulf Oil Corp.

NORTH TEXAS
R. E. Byers, 6000 Lemmon Ave., Dallas 9.

NORTHERN CALIFORNIA
S. D. Stillson, 1324 Everett St., El Cerrito, Calif. Tel. Becon 2-7139
Third Monday, 8:00 P. M., E. Bay Area.
April 16, "Engine Analyzer Operation," Marshall Segrave, Pan-Amer. Airways.

NORTHERN INDIANA
J. Baum Beckman, 547 N. Waller Ave., Chicago 44, Ill. Tel: ES 8-7776
First Wednesday, Meeting at 7:30 P.M., Whiting Community Center, Whiting, Ind.

OAK RIDGE
J. Lundholm, Jr., Eff. A-13, Apt. 241, Oak Ridge, Tenn. Tel: 5-6539
First Wednesday, Meeting at 7:30 P.M., Knight's of Columbus Hall.

ONTARIO
John W. Huether, 311 Southerland Dr., Leaside, Ontario, Canada. Tel: HU-7114
Third Thursday, Meeting at 8:00 P.M. Friendship Hall, College St. United Church, Toronto

PANHANDLE
R. E. Harris, 228 Mays Bldg., Amarillo, Texas. Tel.: 31434.
Third Tuesday, Meeting at 8:00 P.M.

PHILADELPHIA
R. R. Trenner, Rm. 306, 3147 Broad St., Philadelphia 32, Pa. Tel: SA 2-7900
Third Wednesday, Meeting at 8:00 P.M., Bellvue Stratford Hotel.
March 21, "Process Monitoring," E. J. Grace, Jr., Sun Oil Co.

PITTSBURGH
Miss Louise Suckfield, P.O. Box 2038, Pittsburgh 30, Pa. Tel: Hl 1-1800
Fourth Monday, meeting jointly with the Technical Committee on Inspection and Gaging. Dinner at 6:30 P.M., Meetings at 8:00 P.M., Roosevelt Hotel.
March 28, 29, "Instrumentation in the Steel Industry," two-day conference, 14 papers. Roosevelt Hotel.
April 23, "Instrumentation in Chemical Plant Design," R. L. Hurley, Jr., DuPont. Inspection Committee: "Recent Developments in Screw Threads," R. A. Fry, Westinghouse.

PRESQUE ISLE
Edwin P. Schuwerk, 445½ Halley St., L. P., Erie, Pa. Tel: 2-3349
Fourth Tuesday, Meeting at 8:00 P.M., G. E. Community Center, East Lake Rd., Erie, Pa.

RICHLAND
R. A. Nederhood, 2003 Trippe St., Richland, Washington. Tel. 5-4442
Second Wednesday, Meeting at 7:30 P.M., American Legion Hall.

ROCHESTER
R. C. Schwarz, Jr., 1201 Granite Bldg., Rochester 4, N. Y. Tel: Monroe 4610R
Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester, Physics Lecture Hall.
March 27, "Today's Trends & Problems in Control of Oil Refining Processes," H. F. Moore, Std. Oil Co.
April 24, "Practical Uses of Frequency Response Methods for Studying Industrial Process Control," D. W. St. Clair, Kodak Co.

SARNIA
J. J. Connors, 272 Elgin St., Sarnia, Ontario, Canada. Tel: 1970 W
Second Friday, 8:00 P. M., Moose Hall.

SOUTH MICHIGAN
W. J. Sprau, 2509 S. Rose St., Kalamazoo, Mich. Tel: 4-7012.
Fourth Wednesday, 8:00 P. M., Dinner at 6:30 P. M., Chicken Charlie's, Kalamazoo.

SOUTH TEXAS
H. C. Givens, La Gloria Corp., P.O. 637, Falfurrias, Texas. Tel: 122-W
First Thursday. Meeting at 7:30 P.M., Garner Aircraft Instrument School.

ST. LOUIS
W. G. Lee, 4710 Delor St., Tel: FL 8516.
First Wednesday, Meeting at 8:00 P.M., Engineer's Club of St. Louis.
April 4, "High Pressure Instrumentation," C. E. Balcerzak, Bur. Mines, Louisiana, Mo.
May 9, "Principles of Automatic Control," Color-sound film by Akins, Kowalski, Kodak Co.

TOLEDO
Morris L. Conner, 925½ Sherman St., Toledo, Ohio. Tel: MA 9403
Third Tuesday, Meeting at 8:00 P. M., Service Bldg., Toledo Edison Co.
March 20, "Principles of Automatic Control," ISA Color-Sound film.

TENNESSEE
N. M. Taylor, 16 Edgewood, Kingsport, Tenn. Tel: 3338J
No definite night, Dinner at 6:45 P.M., Meeting at 8:00 P.M., Hall's Dining Rm., Bristol Hwy., Kingsport.

TULSA
J. J. Fox, Phillips Petroleum Co., Bartlesville, Okla. Tel: 6600 Ext. 501.
First Monday, Meeting at 7:30 P.M., Engineering Bldg., Tulsa Univ.
April 2, "High Pressure Instrumentation," C. E. Balcerzak, Bur. Mines, Louisiana, Mo.

TWIN CITIES
Alden Hine, c/o Pinkney & Hine, 552 Plymouth Bldg., Minneapolis 3, Minn. Tel.: Lincoln 0523.
Fourth Tuesday, Dinner at 6:30 P.M. Coffman Memorial Union, U. of Minn.

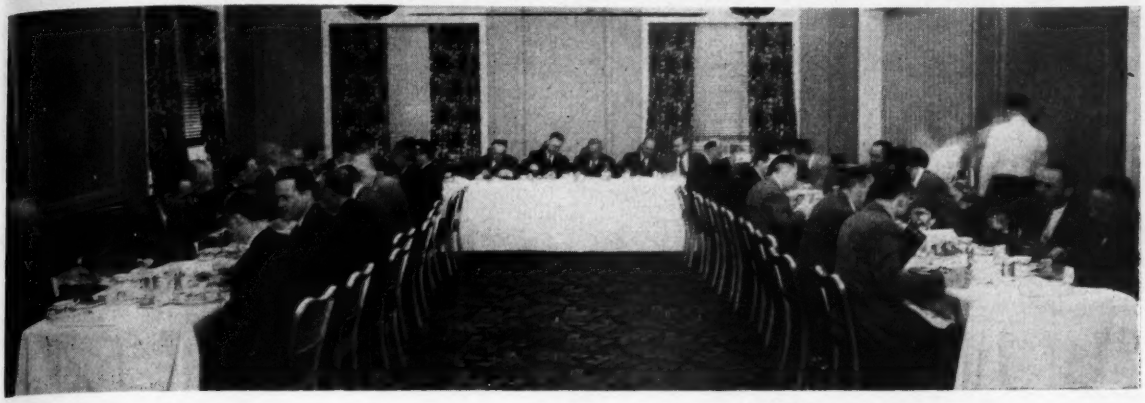
WASHINGTON
Raymond E. Miller, 20-224 Naval Ord. Lab., White Oak, Md. Tel: JU 7-6742
Third Monday, Meeting at 8:00 P.M., P. E. P. Co. Auditorium.
April 16, "Principles of Automatic Control," ISA Color-Sound film.

WAYNE COUNTY
Robert Karr, 2455 Biddle Ave., Wyandotte, Michigan. Tel. 0167J
Third Monday, Meeting at 8:00 P.M., Larson's Cafe, Lincoln Park, Mich.

WILMINGTON
J. E. Charsha, Jr., Hammel-Dahl Co., 1000 Washington St., Wilmington 11, Del.
Third Tuesday, Meeting at 8:00 P.M. Harlan Public School, Wilm.
March 22, "Principles of Automatic Control," Color-sound film by Akins & Kowalski, Kodak Co.

Steel Instrumentation Symposium Announced at Luncheon

Pittsburgh's top industrial leaders attending a luncheon, sponsored by the Instrument Society of America, in the Allegheny Room at the William Penn Hotel on February 14. Symposium "Instrumentation for the Iron and Steel Industry" was announced. Those in attendance are listed below.



Seated, left to right, left table, outside:
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Richard Rimbach, Instruments Publishing Co.
J. C. Fink, Asst. to V. P. Eng'r., Westinghouse Electric Corp.
W. B. Todd, Ex. V. P., Continental Foundry & Machine Co.
W. Prince, Fisher Governor Co.
Carl I. Collins, Pres., Superior Steel Corp.
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Clarke Fry, Westinghouse Electric Corp.
Gwilym A. Price, Pres., Westinghouse Electric Corp.

Head table, left to right:
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Dr. J. C. Warner, President, Carnegie Institute of Technology
R. R. Webster, Jones & Laughlin Steel Corp.
W. P. Witherow, Pres., Blaw Knox Co.
Adm. J. E. Ludewig, Professor, Carnegie Institute of Technology
R. J. S. Pigott, Gulf Research & Development Co.

Right table, left to right, outside:
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L. G. Klingenberg, Chemical Plants Div., Blaw Knox Construction Co.
W. C. Snyder, Jr., V. P., Koppers Co., Inc.
Robert A. Lambert, Jones & Laughlin Steel Corp.
Malcolm F. Hawkes, Professor, Carnegie Institute of Technology
George W. Linkhauer, United Engineering and Foundry Co.
H. C. Riddile, Gen. Mgr., Edgewater Steel Co.

Left table, left to right, inside:
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Charles Cochran, Peter Loftus Corp.
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Harold Fox, Koppers Co.
Carl B. Jansen, Pres., Dravo Corp.
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Right table, left to right, inside:
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Dr. Frederick T. Mavis, Head, Dept. Civil Eng'r., Carnegie Institute of Technology
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TECHNICAL PROGRAM of the Symposium on

INSTRUMENTATION FOR THE IRON AND STEEL INDUSTRY

March 28, 29, 1951—Roosevelt Hotel, Pittsburgh, Pa.

Sponsored by Pittsburgh Section ISA and Carnegie Institute of Technology

Wednesday, March 28

8:30 a.m. Registration (Registration Fee $5.00)

10:00 a.m. Opening Greetings

Chairman: R. R. Webster, Pittsburgh Section President.

"Instrumentation—The Nerves of Industry," J. B. McMahon, ISA Pres.

10:45 a.m. **Production Instrumentation**

Chairman: Bruce B. Bargman, Carnegie-Illinois Steel Corporation.

"Instrumentation and Control in the Utilization of Mixed Fuels and Oxygen in Open Hearth Furnaces," Martin J. Conway, Consulting Engineer, and Edward H. Caugher, Wheeling Steel Corporation.

10:45 a.m. **Inspection & Gaging**

Chairman: James Mulligan, Mesta Machine company.

"Non-contact Gaging of War Material," J. T. Welch, The Sheffield Corporation.

12:30 p.m. **ISA Luncheon**
Hotel Roosevelt, Blue Room.

2:00 p.m. **Forum on Electric, Hydraulic & Pneumatic Servomechanisms.**

Chairman: Andrew J. Fischer, Bethlehem Steel Corporation.

"A Major Advance in Electric Control Systems for Industrial Control Applications," Elwood T. Davis, Leeds & Northrup Company.

"Hydraulic Servo Controls in the Steel Industry," H. Ziebolz, Askania Regulator Company.

"Application Characteristics of Pneumatic Servomechanisms in the Iron and Steel Industry," A. A. Markson, Hagan Corporation.

2:00 p.m. **Inspection & Gaging**

Chairman: J. Paul Sherwin, Carnegie-Illinois Steel Corporation.

"Industrial Application of the X-ray to the Inspection of Steel Castings," J. N. Flanagan, Pittsburgh Ordnance Corps, U. S. Army.

"Methods of Sorting Metals," Antony Doscheck, Doscheck Associates.

7:00 p.m. **ISA Dinner**
Hotel Roosevelt, Gold Room.

Toastmaster: John C. Warner, Carnegie Institute of Technology.

Guest Speaker: Willebald Trinks, Associated Engineers.

Thursday, March 29

9:30 a.m. **Production Instrumentation**

Chairman: D. R. Loughney, Jones & Laughlin Steel Corporation.

"Comparison of Methods of Measuring Molten Metal Temperatures," J. Ward Percy, U. S. Steel Corporation.

"A Thermocouple System for Molten Metal Temperature Measurement," Lester Veiock, Heppenstall Company.

12:30 p.m. **ISA Luncheon**
Hotel Roosevelt, Blue Room

2:00 p.m. **Production Instrumentation**

Chairman: Adin Capron, Babcock & Wilcox Company.

"High Speed Reheating of Seamless Steel Tubes," H. W. Cox, National Tube Company.

"Instrumentation for Controlling the Welding Variable," Julius Heuschkel, Westinghouse Electric Corporation.

8:00 p.m. ASTM Session at Mellon Institute, 4400 Fifth Avenue.

"Stress Analysis in Action," W. T. Bean, Jr., Engineering Consultant.

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Texas does everything in a big way. During the recent trip of Secretary Rimbach to Houston to make preparations for the biggest Instrument Conference and Exhibit, the Texans put on the biggest freeze and Houston's biggest fire. Be sure to come to Texas in September.

Technical Activities of the ISA

By WILLIAM A. WILDHACK

This brief discussion of the technical life of the Society—and suggestions for extending it—is written not only to give you a bird's-eye view of what is going on, but also to invite you to make technical contributions too.

Most members regularly participate in one of the most important technical activities of the Society, in hearing, discussing, or presenting technical talks at ISA Section meetings.

Many of the Sections have technical committees too, and the members serving on those help the other members by preparing special studies or arranging for special meetings or symposiums. In addition, there are upward of 100 members serving on the seven national technical committees, preparing the technical programs for the conferences. At present separate committees are assigned to various branches of the general field of applied instrumentation; relating to production processes, analysis, testing, inspection and gauging, and transportation. Committees on instrumentation education, and on instrumentation research, are at present inactive but are soon to be revived, we hope, because there is obviously much to be done in these fields. As a minimum, we need these committees to keep us all informed of current activities.

If the committee structure is to continue in the general present pattern, there should probably be a number of other committees established—perhaps medical (or biological) instrumentation, (non-communications) electronic instrumentation, military instrumentation, power instrumentation (jet, rocket, atomic), mathematical instrumentation (computers both digital and analogue, simulators, data reducing and analyzing instruments) and others.

If we now had active committees in all these fields we should certainly have far and away too many papers to pack into the five days of technical sessions at Houston, or to publish in the few pages of our small "Journal". But we must not stop writing—or inviting—papers just because there is not time to hear them at annual meetings! Perhaps we should have fewer papers presented in full at the meetings. Other societies have found that 10-minute papers permit a good summary. Personal discussion with the author, or purchase of preprint, can fill in the detail.

Nor should we refrain from writing papers because of publications costs. Rather, I believe, all of us should urge authors who are preparing papers describing significant instrument developments to submit them first to the ISA. Further, we should urge potential authors, who we know are making significant developments, to prepare papers on their work and submit them. A publication program many times larger than we now have is not infeasible. As a minimum, a few additional pages can be added to our "Journal". As another alternative, the Society might arrange for publication of papers in the "Review of Scientific Instruments", perhaps with some share in the advertising receipts of that Journal. Many members have hoped that we could establish a separate journal, and this is also a possible alternative.

So—let's get as many *good* papers submitted as we can. The deadline for submission of papers for full presentation at Houston is almost here, because it takes several months to get them preprinted, but summary presentations

might be possible for some late ones, and at any rate, they will be considered for publication. So, again, let's get papers submitted! Send them to the appropriate committee chairman, or to me.

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Oakland 6, California.

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Forward your letter to INSTRUMENT SOCIETY OF AMERICA, 921 Ridge Ave., Pittsburgh 12, Pa.

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The Mass Flow Meter A Method for Measuring Pulsating Flow

By D. BRAND and DR. L. A. GINSEL *

ABSTRACT. A new instrument for the industrial measurement of mass flow in a pulsating stream is described. This meter, called Mass Flow Meter, consists of a housing in which runs an electrically driven cylindrical rotor. The flow, entering the housing at right angles to the rotor axis, passes on either side of the rotor through gaps between rotor and housing, and leaves the meter on the opposite side. The differential pressure between the two gaps is proportional to the mass flow. A properly damped differential pressure meter connected to the two gaps can therefore be used for measuring pulsating flow. Small scale models and a larger meter have been constructed and tested. From the tests and considerations on the mass flow meters the following conclusions are drawn: (1) The mass flow meter is able to measure satisfactorily the mass flow rate of a liquid, (2) This measurement has even a fair degree of accuracy when the flow is pulsating, (3) As the construction of the mass flow meter is rather expensive, its use will probably be restricted to cases where other methods fail.

Introduction

The measurement of flow is of primary importance to industry. Many types of flow meters have been devised, and several of them are in general use. At the introduction of another basically new type, it seems reasonable to ask why the existing types cannot fulfill all our needs. First we must find out what an "ideal" flow meter should indicate. The answer to this question may vary according to the purpose for which the instrument is used, but in most cases the quantity that is ultimately wanted is mass of fluid passing through the line in a unit time. This quantity, called mass flow rate, is equal to:

$$W = A.\rho.v.$$

where:

W = mass flow (kg./sec. or lbs./sec.)
A = area of the pipe's cross section ($m.^2$ or sq. ft.)
ρ = density of the fluid ($kg./m.^3$ or lbs./cu. ft.)
v = velocity of the fluid averaged over the cross section of the pipe (m./sec. or ft./sec.).

When variations in v and ρ occur, we are interested in the average of the product ρv over a certain measuring time. Ignoring the irrelevant factor A, we conclude that an instrument is wanted that measures the quantity ρv ($kg./m.^2$ sec. or lbs./sq. ft. x sec.).

Methods of Measuring Fluid Flow

Let us see whether the methods of flow measurement hitherto used are able to solve the problem stated above.

1. The instruments most frequently used are of the differential pressure measuring type, including the orifice, nozzle and venturi tube meters. They generate a pressure difference proportional to the product ρv^2. With constant flow, the square root can be taken; this furnishes a fair measure of v when the density of the fluid is known. If, however, either the density varies or the velocity is changing so rapidly that the indicator cannot follow the changes, an error is unavoidable. By damping the differential manometer, an average of Δp over a certain time is obtained, corresponding to the mean of ρv^2. This obviously is not what is wanted; in the case of violently pulsating flow the errors may become very serious. Only if the exact form of the pulsations is known, e.g., in the case of

THE AUTHORS

D. Brand was born in Rotterdam, Holland and graduated at Groningen University. In 1945 he joined Messrs. Werkspoor N.V. at Amsterdam as a physicist, and in 1949 he joined the Royal Dutch Shell Laboratory at Delft.

BRAND

GINSEL

Dr. L. A. Ginsel was born at Poerworedjo, Indonesia. He studied physics at Utrecht University and from 1934 to 1938 was engaged in biophysical research at the University of Amsterdam, sponsored by the Rockefeller Foundation. In 1938 he joined the Royal Dutch Shell Laboratory at Delft.

* Royal Dutch Shell Laboratory, Delft, Holland.

NOTE: Presented before the Fifth Annual Convention of the Instrument Society of America, at Buffalo, N. Y., Sept. 12-18, 1950.

Statements and opinions expressed in these articles are those of the author and not necessarily those of the Society.

a plunger pump, can the error be calculated and a correction applied[1].

Although used in a different way, the Pitot tube should also be mentioned with the group of differential pressure instruments. Seen from the viewpoint of mass flow measurement, the same objections apply as in the former case.

2. The volumetric type of flow meter counts in one way or another a number of calibrated volumes. It thus measures the time integral of v, but does not include in the result the influence of fluid density. The inertia of the moving parts inside the fluid generally causes trouble with pulsating flow.
3. The variable area type flow meter (rotameter) can be compared to a differential pressure type instrument, in which the pressure difference is kept constant and the area of the orifice (annulus between float and tube) varies. It is possible, although not practicable in all circumstances, to make this type of meter indicate mass flow for a limited range of liquid densities and pulsations of low frequency.
4. The viscous flow meter has a linear characteristic and inertia is not a problem, but as the indications are proportional to the fluid viscosity, it is extremely sensitive to changes of viscosity, as for instance those caused by temperature.
5. In 1941, Schultz Grunow[2] published a method for measuring pulsating flow. It consists of two equal orifices in series in the same pipe, the second of which is by-passed; this by-pass contains a constant displacement pump. Let v be the velocity in the main pipe, and c be the constant velocity (caused by the pump) in the by-pass. Then the first orifice produces a differential $\Delta p_1 = \alpha\rho v^2$ (α being a calibration constant) and the second orifice gives $\Delta p_2 = \alpha\rho\,(v-c)^2$. The difference

$$\Delta p_1 - \Delta p_2 = 2\,\alpha\rho vc - \alpha\rho c^2$$

is a linear measure of v; the indication is, however, again dependent on ρ (second term in the equation). Moreover, α being dependent on Reynolds number at least for low values of the flow, no accurate results can be expected on pulsating flows when the flow drops practically to zero during part of the cycle. Other objections to this device are:

   a. poor accuracy, the reading being the result of a rather small difference between two differential pressures;
   b. large space needed for the installation (long straight approach pipes for each orifice).

Several other methods have been proposed, among which we may mention thermal methods, but none of these are extensively used outside laboratories.

It appears that none of the existing flow meters are able accurately to measure a mass flow, in particular under non-stationary conditions. The want of such an instrument is seriously felt in various industries that have to deal with pulsating or rapidly changing flows of liquids or gases.

For this reason in 1941 Prof. dr. W.J.D. van Dijck and some of his students at the Technical University at Delft undertook a research program that aimed at developing an instrument that would be able to fill this gap. The work was sponsored by the "Delftse Hogeschoolfonds"; it was reported on by Van Vugt[3], to whom we refer for a more detailed description of the first models.

The work was later on taken over by the present authors at Royal Dutch Shell Laboratory, Delft.

Principles of the Mass Flow Meter

The principle of the mass flow meter can be considered as an improvement of the Schultz-Grunow method. Whereas in this method one constant auxiliary stream was added to the flow, in the mass flow meter the main stream is branched at the entrance into two parts, and to each part is added a constant auxiliary stream. In one part the main and auxiliary streams have the same direction, in the other part they are opposite.

Fig. 1 shows how this can be attained.

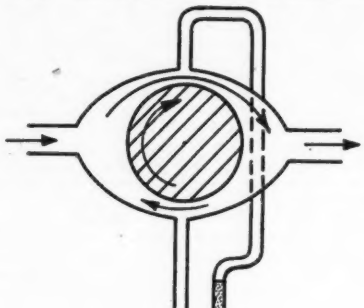

Fig. 1. Principle of the mass flow meter.

The flow entering the meter through the feed pipe on the left, is divided into two parts and passes through two symmetrical measuring gaps on opposite sides of an electrically driven cylindrical rotor; the two streams unite at the outlet of the meter.

The pressure difference between the mid points of the two gaps is measured. When the rotor is not rotating, the velocities in the two gaps are equal; they are proportional to the average velocity v in the feed pipe.

Next suppose the rotor to rotate. In this case a circulating flow is added to the main flows. In one measuring gap the two velocities have the same direction, in the other they are opposite. If we make the simplifying assumption that the circulation is independent of the main flow, we can write for the velocities in the two gaps:

$v_1 = v_m + v_c$ and
$v_2 = v_m - v_c$

where

v_m = velocity in either gap due to the main stream only
v_c = velocity of the circulating stream
v_1, v_2 = total velocity in the two gaps.

If we make now the additional assumption that we have potential flow and that therefore Bernoulli's law is valid for the flow in the meter, we have:

$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$, p_1 and p_2 being the pressures in the + and − gaps.

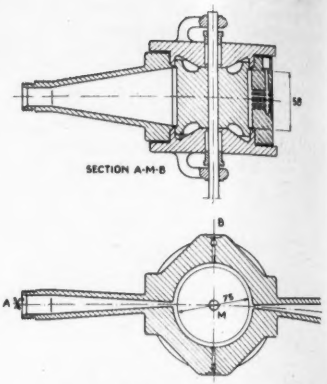

Fig. 2. Construction of M.S.M. 1. Dimensions in mm.

The differential pressure between the gaps is:

$p_1 - p_2 = \frac{1}{2}\rho\,(v_1^2 - v_2^2) = 2\,v_c\rho.\,v_m$

So, if the simplifications introduced above are valid, the mass flow meter gives a pressure difference proportional to ρv_m, and therefore to ρv. When pulsations are present, in principle no difficulty is encountered; the time average of the differential pressure should correspond to the average mass flow. As the velocity of the circulating flow is proportional to the rotor speed, this factor also enters into the expression for the differential pressure; therefore this speed should be kept constant during the measurement.

Of course this explanation of the working of the mass flow meter is too simple to be quantitatively right. The following pages will give some information as to what the meter really does.

Two Small Scale Prototypes

1. M.S.M. 1*

The first mass flow meter was built in 1942 by Van Dijck and R. A. Mees at the Delft Technical University, to test the possibilities of an instrument incorporating the above mentioned principle. It could hardly be expected that this first trial would score a bull's eye; still, it worked rather well and gave the inventors an opportunity to study the causes of deviations from the predicted properties. It was designed for measuring liquid flow in a ¾ in. pipe at low working pressures, and had measuring gaps of constant width. The instrument is shown in Fig. 2.

*) M.S.M. are the initials of Massa Stroom Meter, Dutch for mass flow meter.

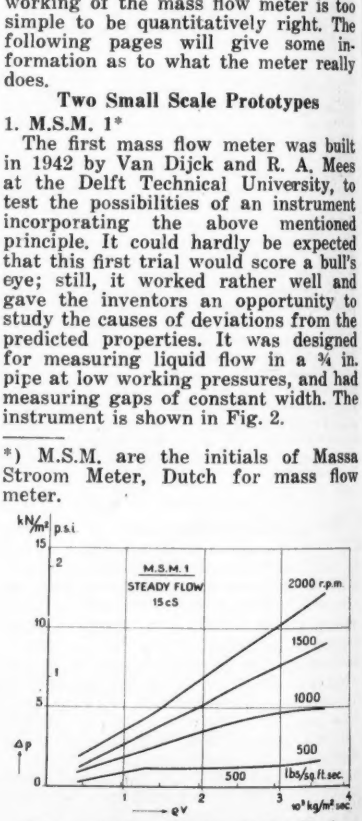

Fig. 3. Characteristics of M.S.M. 1. with steady flow.

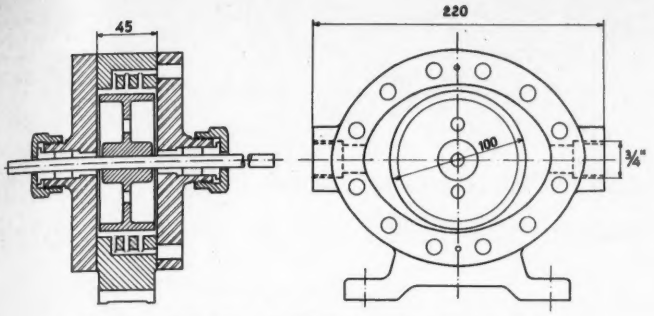

Fig. 4. Construction of M.S.M. 2. Dimensions in mm.

Fig. 3** shows the characteristic of M.S.M. 1 (differential pressure as a function of mass flow); it can hardly be considered linear, particularly for the lower rotor speeds. The pressure loss over the meter was more than twice the measuring differential, mainly owing to the considerable eddy losses occurring in the in- and outlet regions. As can be seen in Fig 2, the transition from the inlet to the cylindrical stator is very abrupt.

The origin of this behavior was recognized by Van Dijck.

We cannot assume that Bernoulli's law (as postulated in theory) is valid in this flow meter, as the transition between the two flows of different velocity (in the channels round the rotor) occurs abruptly in the regions of stream branching (entrance and exit of the flow meter).

2. M.S.M. 2

For this reason, Van Dijck had another model constructed. In order to reduce the abrupt change in velocity at the meeting and dividing parts of the stream, the housing was altered so as to have a quasielliptical form. The measuring gaps of M.S.M. 2 now converge from the inlet to their narrowest parts opposite the rotor, and from there diverge in a symmetrical way to the outlet. In this way, the velocity in the inlet region is kept low, so that the remaining pressure losses there are less harmful. The pressure measuring openings of this meter are situated in the outer wall at the narrowest section of the gaps.

Like its predecessor, M.S.M. 2 was constructed for liquid flow in a ¾ in. pipe, but for a working pressure of 15 ato (220 lbs./sq. in.). Fig. 4 shows two sectional drawings of the meter. It consists of a housing of elliptical shape. The side walls are formed by two cover plates, the rotor axis running in bearings in these covers. The clearance between rotor and cover must be small to avoid leakage along the rotor, which would cause a measuring error. No transition pieces were used between pipe and meter housing.

The test results were much better with this meter than with the first model. Fig. 5 shows some of the results which lead to the following conclusions:

1. The characteristic fairly resembles a straight line for different rotor speeds up to $\rho . v = 3500$ kg./m.² sec. (720 lbs./sq. ft. sec.);
2. In tests with different fluids, the curve did not change when a liquid with a different viscosity was used;
3. The characteristic is exactly the same with pulsating and with steady flow;
4. The pressure loss over the meter is very much lower than with M.S.M. 1; it is comparable to the loss of an orifice meter (vide Fig. 9).

These results proved beyond doubt that a mass flow meter working on the indicated principles was a technical possibility. This does not mean that M.S.M. 2 behaves completely as one would expect from theoretical investigations. Extensive calculations were made before as well as after the construction of the meter, regarding the flow mechanism, the pressure and velocity distribution inside the meter, the influence of eccentricity, etc. There are found to be some discrepancies between these calculations and the test data.

For example, in the test the slope of the characteristic is 18 percent less than calculated. This theoretical calculation took into account the wall friction at the rotor and stator and an approximation of the shape of the housing, as well as the effects of acceleration of the fluid in the gaps. It is wrong to rely too much on these calculations for quantitative results, for it was found that the flow pattern at the inlet and outlet regions has still a considerable influence on the measuring pressure, so much so that if a disturbance of the flow by a vortex or by boundary separation occurs in the first

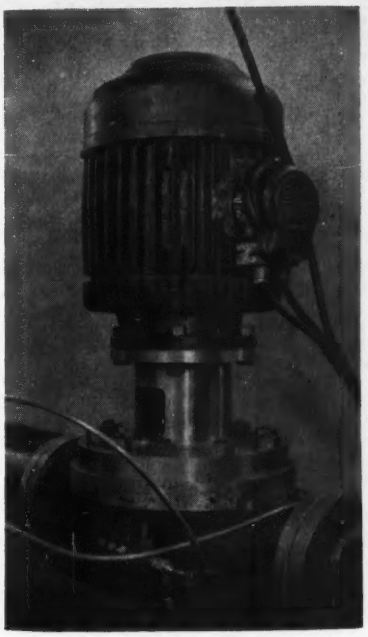

Fig. 6. M.S.M. 3, mounted in a 4 in. test circuit. The upper cover of the meter is a temporary part, which will be replaced by a casting as shown in Fig. 7.

**) In this report we used the metric practical system of units, based on the meter, kg. mass and seconds. The unit of force in this system is called Newton; 1 N. = 10^5 dynes, the pressures are therefore expressed in N./m.², or for convenience, kN./m.² (1 kN./m.² = 0.145 lbs./sq. in.).

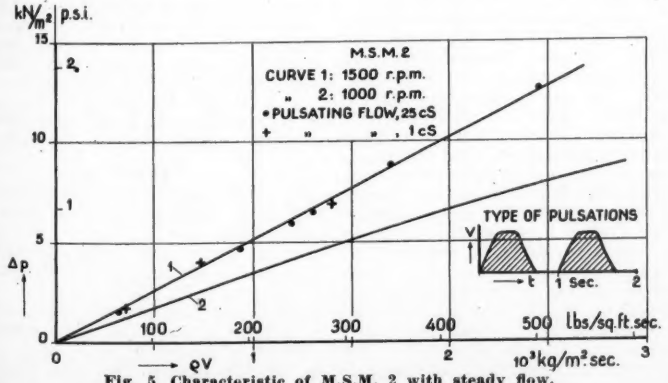

Fig. 5. Characteristic of M.S.M. 2 with steady flow. The points indicate measurements with pulsating flow.

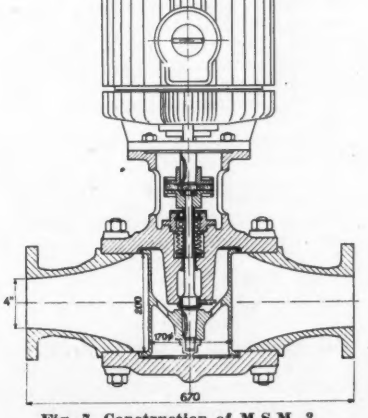

Fig. 7. Construction of M.S.M. 3. Dimensions in mm.

or last 30° of the measuring gap, the whole of the 18 percent difference between test and theory can be accounted for.

Pressure measurements in the inlet and outlet regions have confirmed the hypothesis of serious flow disturbances, which is hardly to be wondered at, as in these regions streams of different velocities meet and divide.

M.S.M. 3

As the second prototype mass flow meter gave good test results, it was decided to use it as a basis for the construction of a large scale meter. The flow in this third meter had to be as similar as possible to flow in M.S.M. 2 in the range where the linearity of its characteristic was assured. At the same time, an effort was made to reduce further the irregularities in the flow at inlet and outlet, and so to improve the general performance of the meter, and in particular the total pressure loss over the meter.

The similarity of flow leads to the following conditions:

1. The ratio of the velocity of the total flow in each gap to the velocity of the rotor surface should be equal for both meters at nominal throughput. We call the velocity of the main flow "critical" if this ratio becomes unity in one of the gaps. It is evident that this critical velocity must mark a change in the slope of the characteristic, as at higher velocity the flow will begin to overtake the rotor locally, and therefore the friction force at the rotor surface will change sign. To be on the safe side, the nominal throughput of M.S.M. 2 was taken as $\rho v = 2000$ kg./m.² sec. (410 lbs./sq. ft. sec.), that is 60 percent of the "critical" value, although deviations from linearity were not important for flows less than 3000 kg./m.² sec. (605 lbs./sq. ft. sec.).
2. The shape of the measuring gaps should be the same. This condition has not been strictly adhered to, as the rotor would then have to be too long. Moreover, a slightly altered shape should, according to theory, give a much larger circulation and therefore larger differential pressure.
3. The Reynolds number of the flow in the measuring gaps should be the same. But it was found that in the present case this condition can be completely neglected, as M.S.M. 2 gave good results over a range of viscosities from 1 to 25 cS. For the larger meter, the equivalent range lies at higher viscosities which is rather fortunate in view of the intended applications with oil.

Consideration of these points led to the construction of a meter for measuring a pulsating flow of 1000 metric tons of oil per day. This meter gives a differential pressure at maximum flow of about 18 kN./m.² (72 in. water column). Figs. 6 and 7 give an impression of the instrument.

Construction

The housing is a heavy steel casting, which is designed for a working pressure of 20 atm (300 lbs./sq. in.). As it incorporates transitions from the main elliptical part with a width (rotor length) of 200 mm. (8 in.) to the 4 in. end flanges, its shape is much more complicated than that of M.S.M. 2.

The rotor axis is vertical, and has its bearings in the upper cover only; this cover also carries the motor which is an oversize three-phase current motor in an explosion proof housing. A rather heavy motor was chosen to ensure a constant speed in all circumstances, which is necessary for reliable measurements.

A sealing device guards against leakage of the measuring fluid from the meter through the bearings.

Testing

The meter was tested with oils of a viscosity of 35 cS. and 5 cS. respectively. The oil flows from an elevated tank with a controlled level, through the meter to a weighing tank and from there back to an underground reservoir, out of which the elevated tank is kept filled by a centrifugal pump.

In the metering circuit a cylindrical plug valve is inserted which can be rotated at a speed of 60 rpm. By this means a violently pulsating flow with 120 pulsations/min. can be obtained.

The test results are shown in Fig. 8. Compared with those of M.S.M. 2, they are less favorable, as slight deviations from linearity begin to occur with a flow as low as 1000 kg./m.² sec., that is at 40 percent of the critical flow, whereas M.S.M. 2 has a linear characteristic up to 90 percent of the critical flow.

For practical purposes, however, this is not a very serious defect, as the curvature of the characteristic at slightly higher flows is not very pronounced. The possibilities of measuring pulsating flow are therefore not affected very much. Even with the very severe pulsations used for testing, no difference between the steady and pulsating flow curves was found in the lower half of the characteristic. Only at higher flows some deviations occur, but these never exceeded 8 percent. They can be fully explained from the above mentioned curvature of the characteristic. With the smaller pulsations encountered in practice, much smaller errors can be expected.

The effect of changing the viscosity from 35 to 5 cS. is slight. The deviations, which amount to a few per cent, lie within the measuring errors.

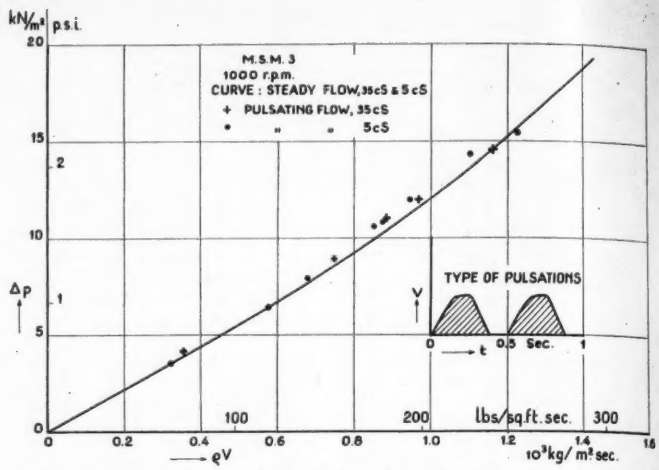

Fig. 8. Characteristic of M.S.M. 3. The points indicate measurements with pulsating flow.

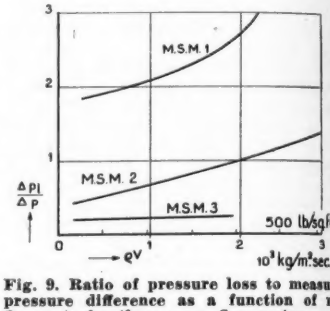

Fig. 9. Ratio of pressure loss to measuring pressure difference as a function of mass flow rate for three mass flow meters.

As a result of streamlining the entrance and exit passages of the meter, the pressure loss has come down to very low values. This loss is less than one quarter of the measuring pressure difference (with an orifice, the loss depends on the diameter ratio and usually lies between 60 and 90 percent of the differential pressure). Fig. 8 shows the ratio of pressure loss to measuring pressure for the three mass flow meters; the improvement is evident from the three curves.

As the indication of a mass flow meter is proportional to ρv, there is a possibility that it might be able to measure two phase flow, e.g. an air/liquid mixture.

Some trials were made to test this; they yielded unsatisfactory results, the differential pressure coming out much too low. Probably, the flow has become disturbed by segregation of air bubbles and unequal repartition of these.

The power consumption proved to be 0.4 kW, when a liquid of a viscosity of 5 cS. passed through the meter.

Conclusions

From the tests and considerations on the mass flow meters the following conclusions are drawn:

1. The mass flow meter is able to measure satisfactorily the mass flow rate of a liquid.
2. This measurement has a fair degree of accuracy even when the flow is pulsating.
3. As the construction and operation of the mass flow meter is rather

expensive, its use will probably be restricted to cases where other methods fail.

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Continuous Electronic Recording of the Water Content of Oil Field Emulsions

By P. O. ENGELDER*

ABSTRACT. Operating theory, design features, and typical field applications of an electronic instrument capable of providing a continuous record of the water content of crude oils and petroleum products, as they flow through pipelines, are described in detail. Effects of such factors as temperature, salinity, globule size and distribution, and type of crude are discussed. Limitations of the instrument, as indicated by field experience to date are enumerated.

IT IS generally agreed that the origin of petroleum is to be found in the bacterial modification of organic material deposited in marine sediments, notably silts. [1 and 2] Furthermore, despite isolated discoveries of petroleum in strata deposited under subaereal conditions, the necessity for the existence of source sediments of marine origin either contiguous to the reservoir strata or within the range of migratory waters has been clearly demonstrated.[3] The weight of evidence indicates that the circulation of vast volumes of connate water necessarily accompanies petroleum accumulation. Clays and silts, in compacting under the weight of their sedimentary overburden to form shales, are known to reduce their pore volume by several times, resulting in the expulsion of similar volumes of fluid which must, of course, migrate. Siliceous and calcareous cementing material is precipitated within sand strata in amounts far greater than the quantity of solids that could possibly be held in solution by quiescent water in the pore volume. We are forced to the conclusion that the occurrence and migration of subterranean water plays a vital role in the origin and accumulation of petroleum.

This inescapable alliance is indeed unfortunate, for water represents the greatest single problem the oil producer must face. Although water is practically insoluble in oil, it is well known that crude is produced from wells with a high water content. This water is frequently emulsified and is a source of great technical difficulty. Production costs are increased, the marketability of the oil is adversely affected, and corrosion problems are intensified. Furthermore, the appearance of water in the well frequently results in a decrease of net oil production, due to a combination of increased hydrostatic pressure within the well and lowered relative permeability to oil of the producing formation as a result of preferential wetting of the sand grains by water. The magnitude of the problem becomes apparent when it is realized that over 30 per cent of the crude produced in the United States contains emulsified water in appreciable quantities.

Thus the determination of the water content of an oil field fluid is seen to be a matter of paramount importance, and, to be sure, routine laboratory measurements have been conducted since the industry was in its infancy. Present day technique consists of the withdrawal of small samples, at periodic intervals, and the determination of the water content of these samples by physical means such as distillation or centrifuging, or, in rare cases, by chemical means such as Karl Fischer tests or dioxane extraction. Fluid inhomogeneity adversely affects the accuracy of sampling, for the sample rarely represents more than the minutest fraction of the flow. In addition, the practice is subject to human error—"the accuracy of sampling is inversely proportional to the state of fatigue of the gauger"—and it further suffers in validity as a result of the time inconsistency of well production. If the "cut" is relatively constant with time as illustrated in Fig. 1, physical sampling yields valid results, but the condition depicted in Fig. 2 is often encountered; the validity of any single sample throughout the 24 hour period covered by this chart is questionable, to say the least!

Furthermore, it is advantageous in certain operations in the dehydration plant or the refinery to have a know-

* Oil Well Water Locating Co., Long Beach, California.

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No. 1. "The Science of Petroleum," A. E. Dunstan, Oxford University Press, London.
No. 2. "American Association of Petroleum Geologists," Volume 30, pp 645.
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THE AUTHOR

P. O. Engelder, recently returned to active duty with the Marine Corps, received his M.S. at California Institute of Technology in 1940. During World War II he was in artillery and radar procurement with the Marine Corps. He has had two years postgraduate work at Caltech and for four years has been chief research and development engineer for the Oil Well Water Locating Company, Long Beach, Calif.

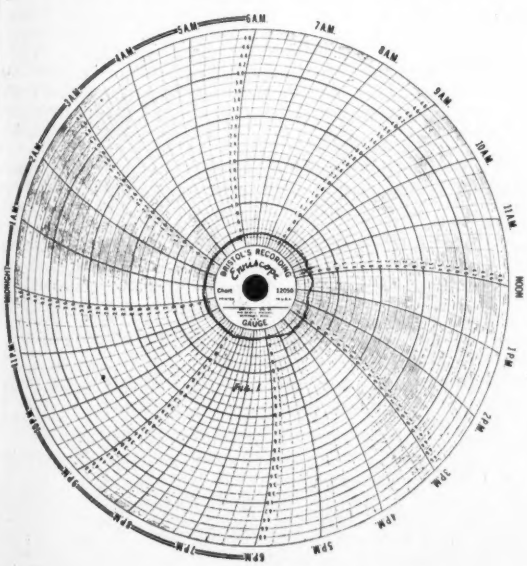


Fig. 1.

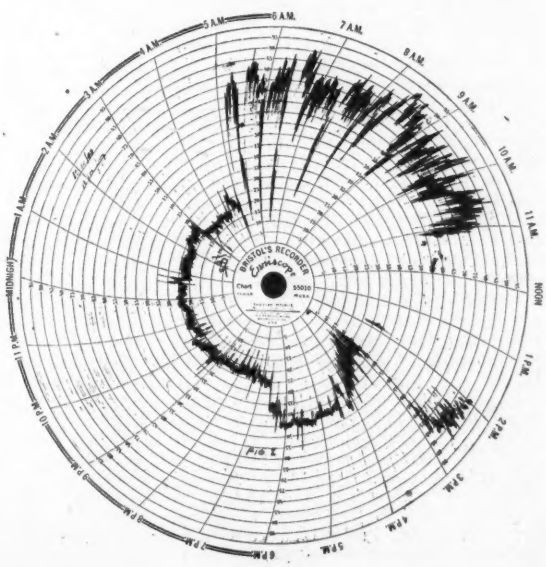


Fig. 2.

ledge of the water content of the stream at all times; if the "cut" is changing rapidly, a prohibitive number of physical samples would be required. Obviously, a fully automatic instrument capable of providing a continuous record of the variation in water content is needed; equipment of this sort is pictured in Fig. 3 and will be described in this paper.

The physical basis of the measurement made by this equipment resides in the determination of an electrical characteristic of the emulsion known as the dielectric constant, which, due to the polar nature of the water molecule and the resulting high dielectric constant of water, is a sensitive indicator of water content.

Water may be carried mechanically in oil in either or both of two forms: (1) as microscopic droplets remaining in suspension primarily due to the viscosity of the crude, and (2) as a true emulsion, in which droplets of water of microscopic size are prevented from aggregating through the formation of protective membranes at the oil-water interface. In actual practice both of these conditions are encountered, often simultaneously. Furthermore, when the water content is extremely high, the fluid aggregate consists of globules of oil supported in the water stream.

Before continuing a discussion of the equipment itself it would, perhaps, be well to review briefly some of the more important physical characteristics of emulsions and emulsion formation. A true emulsion is a system consisting of two liquid phases, one of which is dispersed as globules within the other. The two liquids must be immiscible, or nearly so; e.g., the true solubility of water in oil is of the order of 0.05 per cent and the true solubility of oil in water is practically nil. The liquid broken up into globules is known as the dispersed, or internal, phase; while the component surrounding the globules is termed the continuous, or external, phase. Two families of emulsions are theoretically possible, depending upon whether the water is dispersed in the oil, or vice-versa. In all emulsions with the exception of the very dilute oil-in-water type, the oil hydrosols, the presence of a third substance, the emulsifiying agent, is necessary to add stability to the system. Asphaltic material, argillaceous material in colloidal suspension with the oil, or both, serve as emulsifying agents in most oil-field emulsions. Agitation, or other physical disturbance resulting in the dispersal of one phase throughout the other in the presence of the emulsifying agent, promotes emulsion formation. Widely accepted theory at present postulates an absorbed film, an interfacial membrane, surrounding the dispersed globules of the internal phase, thus preventing their coalescence and resulting aggregation under the influence of gravitational differentiation.

It has been quite definitely established that oil-field emulsions are formed in the production equipment of the well, although a remote possibility of emulsification occurring upon the emergence of production fluids from the sand face into the well bore may exist in some cases. The vast majority of oil-field emulsions are of the water-in-oil type. Size-frequency analysis shows that the dispersion of the globules of water may vary throughout a wide range, both in any one sample and from one well to another. In some extremely "tight" emulsions the globules are from 1 to 5 microns in diameter; coarse emulsions have been encountered in which the globule diameter ranged from 25 to 200 microns. The water, in practically all cases, carries dissolved salts, mainly NaCl, in concentrations ranging from a few hundred grains per gallon to saturation.

Extensive laboratory experiments have been conducted on both synthesized emulsions and field samples to determine the effects of water contamination on various electrical properties of the emulsions, namely, the dielectric constant, the loss tangent, and the conductivity. The conductivity is dependent upon the type of emulsion, i.e., whether water is the internal or the external phase, and consequently is of little value as a quantitative index of water content. The loss tangent is a measure of the angle by which the current through a dielectric fails to lead the voltage 90°; it is thus a function of the power loss in the dielectric and is an exceedingly important electrical characteristic of any dielectric. One may define the dielectric constant as a measure of the work required to orient the molecules, under the influence of an external electric field, against their random thermal agitation.

Water exhibits an anomalously high dielectric constant, a value of 78 compared to 2.2-2.4 for petroleum; to aid in a more complete understanding of the source of this high value, it is helpful to introduce the concept of a polar molecule. A polar molecule lacks electrical symmetry; its centers of positive and negative charge are separated by a fine distance, and consequently it is difficult to orient and will oscillate rotationally when placed in an alternating field, thus dissipating energy. On the other hand, a non-polar molecule, one possessing physical and electrical symmetry, is capable of being oriented by an external field with much greater ease, and, theoretically, exhibits no power loss when placed in an alternating field. The net result is a tremendous contrast in dielectric constant and loss tangent between the highly polar water molecule and the non-polar petroleum, thus imparting great sensitivity to water determination methods based on a measurement of these two dielectric properties. Both loss tangent and dielectric constant as a function of water content are plotted in Fig. 4; the test frequency employed was 10 megacycles per second, the oil employed was highly refined and had a measured dielectric constant of 2.25 and no measurable power loss, the water had a salinity of approximately 250 grains per gallon.

The Enniscope equipment takes advantage of these effects by passing the fluid to be measured through a capacitor comprising two concentric cylinders inserted at a suitable point in the pipe line and energized by a source of high frequency energy. The electronic equipment generating this energy and the associated measuring circuits are housed in a rugged, weatherproof condulet, connected to the recorder through electrical conduit and to the electrode assembly through shielded, weatherproof coaxial cable. The relation of the various components is illustrated in the block diagram, Fig. 5. Radio frequency energy is fed to the electrode assembly through the coupling network; changes in the capacitance and loss tangent of the test capacitor (functions of the water content of the emulsion) cause varying voltages to appear at the input of the vacuum tube voltmeter. Corresponding changes in the plate current of the voltmeter stage are employed to alter the impedance of a specially designed saturable reactor which in turn controls the deflection of a circular chart recorder. A resonance type voltage regulator is included in the equipment; about 25 watts of 115 volt, 60 cycle alternating current is required to operate the entire instrument.

Through a proper choice of operating frequency, electrode geometry, and circuit constants, reasonable linearity may be obtained. A typical accuracy plot, obtained by plotting chart reading vs. centrifuged water content for a large number of samples, is shown in

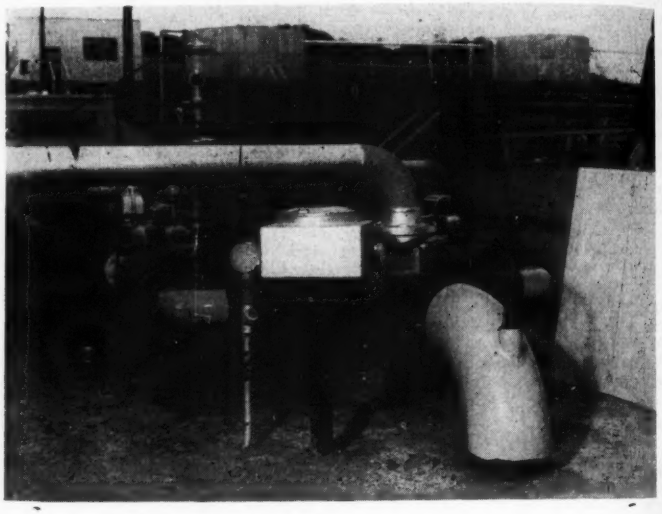


Fig. 3.

Fig. 6. This plot is interesting in several respects. Some points deviate grossly from the faired curve, which is substantially linear; in the author's opinion, these points represent contaminated samples. The trend is too obvious and the weight of laboratory and field experimental evidence is too great to permit one to attribute the gross discrepancies to the electronic equipment. Smaller disrepancies between chart reading and physical water content may be attributed to several factors. First, considering industry-wide sampling technique in general, one will admit that the actual water content of a sample is rarely known with greater precision than 0.2 per cent; as a matter of fact, ASTM standards permit a margin of 0.4 per cent between two results from any one sample. Second, the accuracy of the present Enniscope equipment in the 0-10 per cent range, for example, is limited to approximately plus or minus 0.3 per cent, due primarily to the effect of globule size and distribution, fluid temperature, and suspended (not dissolved) solids. Suspended solids cause a slight increase in the Enniscope indication, but this condition is difficult to evaluate in the field inasmuch as these solids will distort and perhaps even invalidate a water content determination by centrifuge—of course, distallation will provide a true determination of water content in this case.

As one might expect, the indications are substantially independent of salinity as long as the hydrocarbon forms the continuous phase of the emulsion. The salinity of the water must be considered, however, when oil-in-water emulsions are being measured. At 75 per cent water, for example, with oil the internal phase, the instrument will read approximately 8 per cent higher if the water has a salinity of 1500 grains per gallon than if 50 grains per gallon water is employed.

All the radio frequency circuits are temperature compensated, and the indications have been demonstrated to be independent of ambient temperature excursions of from 25 to 115°. Increase in fluid temperature results in a slight decrease in instrument reading, insufficient to warrant compensation unless extreme precision is required.

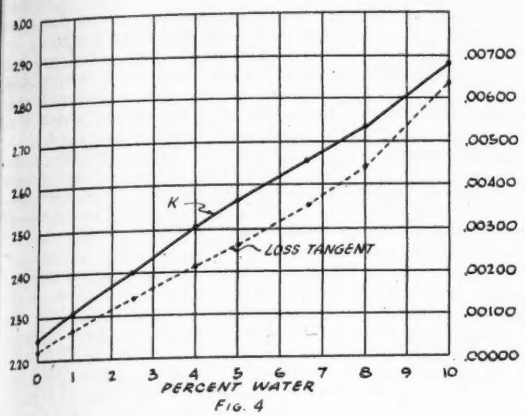


FIG. 4

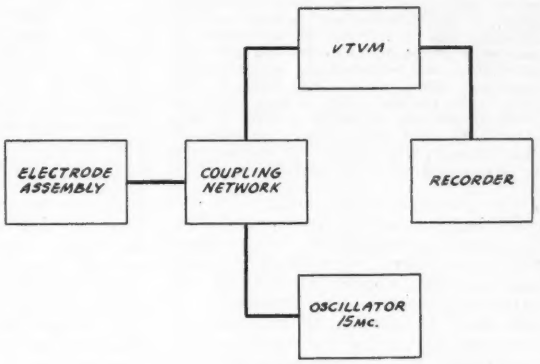


Fig. 5.

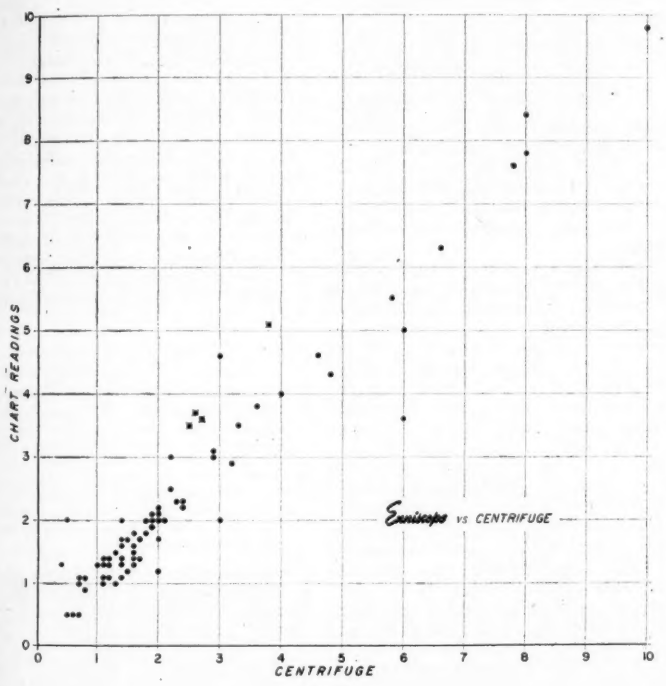


Fig. 6.

The four starred samples in the 2-4 per cent region of Fig. 6 illustrate an interesting point, perhaps the most serious limitation of the instrument. These samples represent readings made on a crude that was heavily diluted with a gas oil containing a high percentage of aromatic hydrocarbons. This was done to reduce the viscosity of the crude for ease of pumping and handling. The contamination of the crude by the gas oil containing a high percentage of polar molecules resulted in erroneous chart readings, for the instrument responded to the presence of these aromatic hydrocarbons as well as to water, although to a lesser degree, of course. Compared to a sample of the crude oil, the gas oil in question exhibited a dielectric constant equivalent to a 3 per cent water content, although it actually contained only a trace of water. Consequently, it is important that the instrument be calibrated with the type of crude with which it is intended to be used, and the possibility of contamination of the fluid by polar hydrocarbons be considered.

This equipment has been proven in actual field practice over a period of three years. Literally thousands of spot checks for accuracy have been made and hundreds of emulsions studied in the laboratory. Maintenance has consisted largely of tube replacement at six-month intervals. Properly calibrated, the instrument provides a continuous record of "cut" that approaches the accuracy provided by careful physical sampling technique, with the prime advantage that human errors in sampling and laboratory technique are virtually eliminated and a complete chronological record of water content variations is available rather than the results of spot samples taken at intervals.

A Simplified Thermocouple for Temperature Measurements in High Velocity Gas Streams

By H. M. BEEDE and C. R. DROMS *

ABSTRACT. A thermocouple with a high recovery factor, suitable for measuring temperatures of high velocity gas streams, has been developed and is described in this paper. A description of the test facilities and characteristics of several variations of design of this stagnation thermocouple is also included. Test results show the best design to have a recovery factor of 0.95 plus or minus .01 over a range of velocities from 450 to 575 ft. per second, a range of angle of yaw from 0 to plus or minus 45 degrees, and immersion from 2.5 in. to 5 in.

The development of modern jet aircraft engines has served to emphasize the growing importance of temperature measurements in high velocity gas streams. In order to evaluate the performance of a jet engine, it is necessary to be able to measure the temperature of the air entering the compressor. The accuracy of the performance calculations depends partly on the accuracy of the inlet air temperature measurements. Therefore, it is desirable to be able to measure this temperature as accurately as possible under test conditions. The work described in this paper was undertaken to design a thermocouple with a maximum recovery factor for measuring the total temperature of the high velocity inlet air.

Inlet air temperature thermocouples have customarily been located in the inlet passage leading to the compressor. It is estimated that velocities of at least 500 ft. per second are reached in this region. For test purposes on a jet engine, it is preferable to use the total temperature of the inlet air, as this temperature is more nearly a representative measure of the total energy content of the air. Total temperature, commonly referred to as stagnation temperature, is the temperature which the inlet air would reach if it were stopped adiabatically, thereby converting its kinetic energy to heat energy, and raising the temperature of the air. In comparison, static temperature is that temperature which would be indicated by a thermo-sensitive element if there were no relative motion between the element and the air. The difference between total temperature and static temperature varies with the square of the velocity of the moving air, according to the following relationship:

$$\text{TOTAL TEMP.} - \text{STATIC TEMP.} = \frac{V^2}{2gJC_p} \approx \frac{V^2}{12{,}000}$$

where

V = velocity in ft./sec.

g = acceleration due to gravity, ft./sec.^{2}

J = mechanical equivalent of heat, ft./lb./BTU.

C_p = specific heat of air at constant pressure, BTU/lb.° F.

At 500 ft. per second, the difference between the total and static temperatures is 20.8 F. for air at room temperature.

As explained above, in order to measure the total temperature it would be necessary for the thermo-sensitive element to stop the air completely, recover all its kinetic energy, and then convert it to heat. Various losses involved in such a device have made an exact measurement of total temperature impossible. For comparing the efficiencies of various designs, however, the temperature recovery factor of a thermo-sensitive element or probe has been defined as the ratio of the measured temperature rise to the adiabatic temperature rise, or

$$\text{Recovery Factor} = \frac{\text{Probe Temp.} - \text{Static Temp.}}{\text{Total Temp.} - \text{Static Temp.}}$$

It can be seen that a recovery factor of unity is desirable for the most accurate direct indication of total temperature, eliminating the possibility of error in making and applying corrections to the recorded temperature readings.

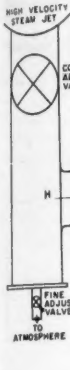
With the obvious advantages of total temperature thermocouples in mind, it was decided to design a thermocouple probe suitable for production and development test measurements of jet engine inlet air temperatures. A study of several of the more promising designs described in earlier literature indicated that most of the designs were for small probes and thermocouple wire. This small size was necessary to minimize the effects of conduction and to more nearly correspond to the size of test equipment available to the investigators. As a result of this study, the decision was made to concentrate on the design of a larger probe, of sufficiently sturdy construction to eliminate any possibility of damage to the engine through breakage of the thermocouple during test.

Thermocouples being tested were compared to a reference thermocouple, with both placed in the air stream (Fig. 1). The test thermocouple was placed in a region of high velocity air flow, and the reference thermocouple in a region of low velocity flow where the total and static temperatures were very nearly equal. Since the total temperature of the air stream was nearly constant through the two sections, the difference in readings of the two thermocouples was then an indication of the recovery factor of the test thermocouple. The velocity of the air stream was measured by pitot tubes located downstream from the test section. All tests were made at an air flow velocity of 525 ft. per second, except for additional tests on the final design.

As shown in the test setup, one end of the 6 in. test pipe was connected to a steam jet through a control valve. The steam jet lowered the pressure at the downstream end and caused air to flow through the pipe. The test section was connected through a wooden nozzle to a 12 in. pipe which served as the reference section. The reference section was then connected through piping to the outside atmosphere. Ambient temperatures around the test section varied from 75 to 100 F., while the total temperature inside the test section was essentially outdoor temperature.

The air velocity in the reference section was calculated from the measurement of velocity in the test section. A maximum correction of approximately 0.1 F. was applied to the temperature indicated by the reference thermocouple, thereby correcting for the reference section air velocity. Calculations also were made to determine the amount of heat added to the air as it flowed from the reference section to the test section. The maximum correction calculated for this additional heat was approximately 0.2 F. The total correction is 0.3 F. This correction was applied to obtain the thermocouple recovery factor of the fuel design.

The difference in output between the reference thermocouple and the test thermocouple was indicated by the 200



THE AUTHORS

H. Martin Beede attended Northeastern University and in 1937 was graduated with the B.S. degree in Electrical Engineering. Employed by the Vulcan Electric Co., and in 1938 the Picker X-ray Co., Beede joined the Thomson Laboratory of the General Electric Company's Lynn River Works in 1940, and has since been employed as a technical engineer in temperature measurements.

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microvolt self-balancing recorder (Fig. 2). To measure absolute values of the temperature, one thermocouple was shorted out, and the voltage across the 0.001 ohm resistor increased until the recorder was again on scale. The thermocouple output was then the sum of the known voltage across the shunt plus the voltage indicated by the recorder.

As a prelude to the testing of total temperature thermocouples, some tests were made on bare wire thermocouples similar in construction to those already in use. At this time the reference section had not been completed. Comparisons were made by placing the two thermocouples in the test section. One of the very interesting observations was the effect of rotating a bare wire thermocouple about its axis perpendicular to the air flow (Fig. 3). A drop in the temperature of the thermocouple occurs at the 90° and 270° positions, where the air flow is parallel to the plane of the wires. It was noted also that for the chromel-alumel thermocouple the drop is the same magnitude at both 90° and 270°. The copper-copnic constantan thermocouple, on the other hand, has temperature drops of unequal magnitudes at 90° and 270°, the drop being greater when the copnic wire is upstream. This drop is probably caused by the formation of a low temperature stagnant air pool behind the upstream wire. When the airflow is parallel to the plane of the two wires, one wire is in the pool formed by the other wire, and the junction temperature is lowered due to heat loss to the pool. The thermal conductivities of chromel and alumel are more nearly equal, so that little difference can be noticed when their positions are interchanged. Because of the much larger difference for copper and copnic, the cooling is much more pronounced when the copper wire is in the stagnant pool.

The first design of total temperature thermocouple tested was the one shown as "E" in Fig. 4, which consisted of a thermocouple enclosed in a stainless steel tube, with a large entrance hole and a small exit hole. This provided a stagnation chamber to stop the air flow, and allowed for some circulation of air to permit the thermocouple to follow temperature changes more quickly. The ordinates of these curves are plotted as "microvolts differential," and refer to the difference, in microvolts, of the test and reference thermocouples. An increase in the microvolt differential represents a decrease in the recovery factor of the test thermocouple.

Tests were made to determine the optimum dimensions of the thermocouple "E". Factors considered were the sizes of the entrance and exit holes, and the location of the exit hole and the thermocouple bead. The results show that a maximum size entrance hole is best, to provide for an adequate flow of air. The exit hole has an optimum diameter of 0.100 in., any smaller diameter constricting the air flow, and lowering the thermocouple temperature. Any greater exit hole should be as high as possible, for maximum purge of the chamber. The thermocouple bead should be directly in the center of the entrance hole.

In reports of other investigators, references have been made to a spade-type thermocouple, similar in outline to the thermocouple shown as "D" in Fig. 4. To test for optimum dimensions of this thermocouple, a set of removable tips was made, with varying dimensions. These tests indicated that the effective entrance area should be as large as possible. Tests of thermocouple bead position indicated that the bead should be located as far down in the cup as possible, and slightly to the rear of center. Better results were obtained with the exit hole above the edge of the cut.

Two thermocouples were constructed, one of the optimum dimensions for thermocouple "E", and the other of optimum spade type. Results showed the recovery factor of the spade type to be higher over the range of velocities tested. On this basis it was decided to proceed with modifications of the basic spade design.

A number of variations of the basic spade design were built. The results of orientation tests of the modified spade thermocouple and thermocouple "E" are shown in Fig. 4. The thermocouple "C" showed less sensitivity to changes in the angle of yaw, and was chosen for further development. This type is called a closed spade, and is the best basic design found in the series of tests.

After comparing the various designs at the same immersion depth, the effects of immersion variations were studied by taking temperature traverses with various modifications of the closed spade type. A series of tests were made varying the sizes of wire, shield diameters, and shield materials, to change the effects of conduction of heat along the lead wires. To explain the shape of the curves for varying immersions, the following theory was advanced: starting from minimum immersion, the effects of ambient temperature are predominant, and the thermocouple temperature is above the total temperature. As the immersion is increased, the conduction along the wire and the protective shield decreases, causing the indicated temperature to drop. Just beyond the center of the pipe, the losses of heat from the steel shield due to its low recovery factor, and the heat added from the wall and ambient air, are in equilibrium for a short distance. At this point, the temperature curve levels off. Beyond this point, less heat is added from the wall due to the increase in path length, and more of the heat lost by the steel shield is taken from the stagnation section, causing the indicated temperature to drop. Thus, heat conduction produces two effects: at small immersions, conduction of heat from the ambient air and the pipe wall to the bead through the wires and shield raises the bead temperature; at larger immersions, heat is conducted away from the bead through the wires and the shield to that portion of the shield which is in the high velocity air stream. Because of its lower recovery factor, the shield is at a temperature lower than that of the bead, causing heat to flow from the bead to the shield.

Further proof of the theory is seen in comparing traverses taken with varying wire and shield sizes. All point to the fact that increasing the thermal resistance between the shield and bead decreases heat loss through

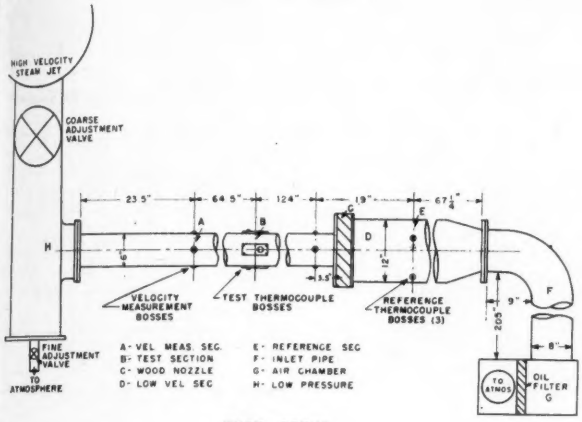


Fig. 1.

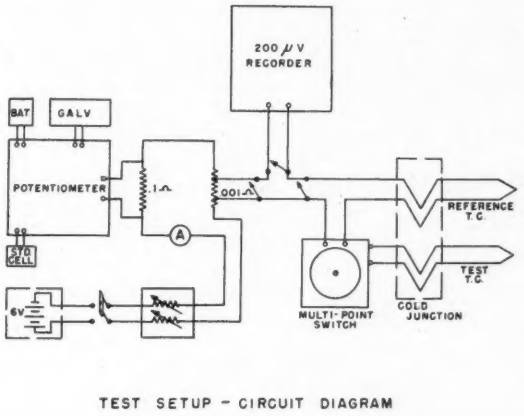


Fig. 2.

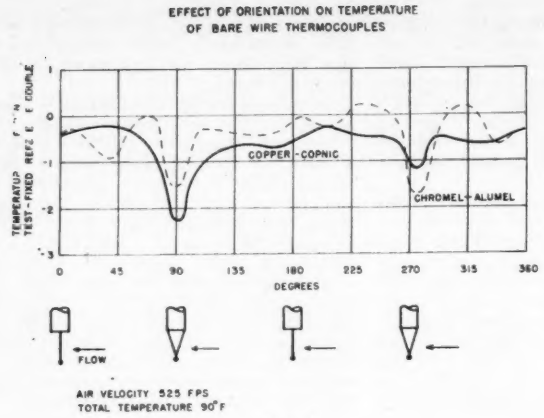


Fig. 3

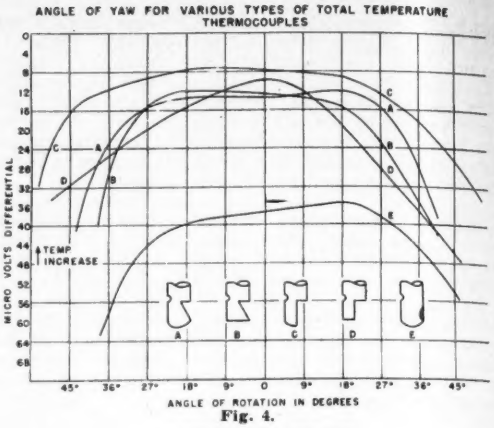

ANGLE OF YAW FOR VARIOUS TYPES OF TOTAL TEMPERATURE
THERMOCOUPLES
MICRO VOLTS DIFFERENTIAL
TEMP INCREASE
ANGLE OF ROTATION IN DEGREES

Fig. 4.

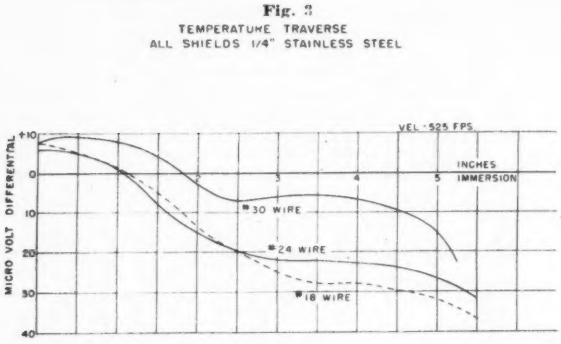


Fig. 5.

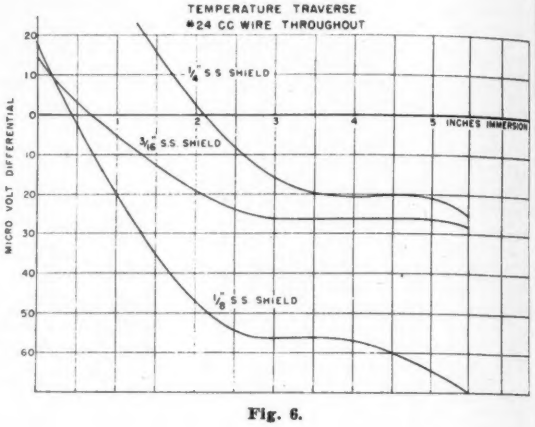


Fig. 6.

the shield and raises the indicated temperatures.

Fig. 5 is a plot of traverses taken with thermocouples having the same size shield (one quarter in.) and varying wire sizes, indicating that a progressive decrease in wire size (and increase in thermal resistance from shield to bead) causes higher bead temperatures. Fig. 6 shows traverses taken with thermocouples all having the same size wire (24 gage) but with varying shield sizes. They indicate that increasing shield size (and increasing thermal resistance from shield to bead) also causes an increase in bead temperatures.

A further indication of the effects of varying heat loss through the shield is shown in Fig. 7 where temperature traverses are plotted for two thermocouples having 24 gage wire, one with a one quarter in. stainless steel shield and the other with a one quarter in. textolite shield. Decrease of heat conduction down the shield causes the textolite shielded thermocouple traverse to level off at a smaller immersion than the stainless steel shielded thermocouple while an increase in the thermal resistance of the textolite shield decreases its losses and causes a higher indicated temperature.

Another type of thermocouple built and tested was called the "Closed Spade-Plate Tip", shown in Fig. 8. This thermocouple is built to increase the surface area between the thermocouple bead and the stagnant air pool and to increase thermal resistance from bead to shield. It is built with a one eighth in. shield and 30 gage wire.

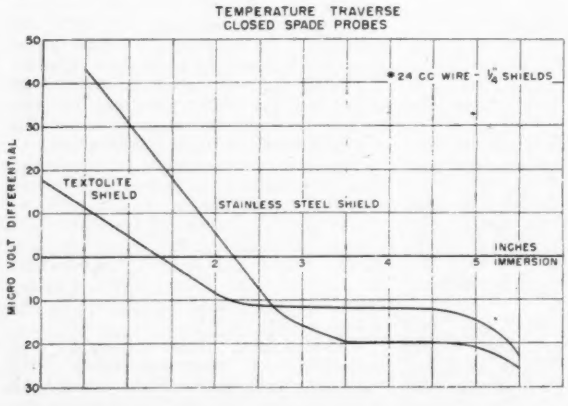


Fig. 7.

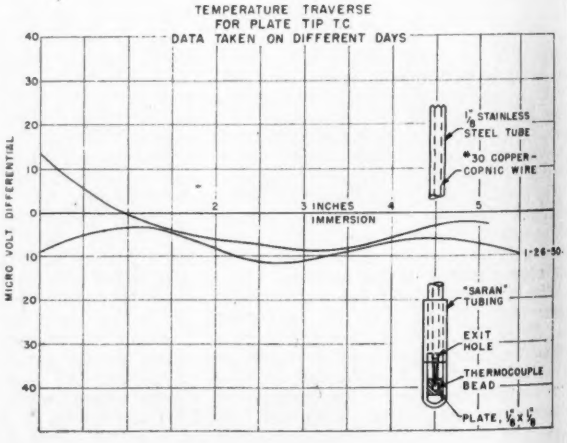


Fig. 8.

The level portions of the two temperature traverses taken with this thermocouple indicate a recovery factor of approximately 0.97.

Tests were run to check the possible variations in indicated temperature due to changes in relative humidity. The results of these tests showed no conclusive evidence of variations of great enough magnitude to have any noticable effect on the temperature readings.

Of the various types of total temperature thermocouples tested, the "Closed Spade" type with one quarter in. shield and 24 gage wires, was tne best design, considering its sturdy construction and high recovery factor. Additional tests were run to determine more accurately the characteristics of this thermocouple. It was found (Fig. 9) to have a recovery factor of 0.95± .01 over a range of velocities from 450 to 575 ft. per second and through an angle of yaw of ±45° (Fig. 10), and a constant temperature indication with one quarter degree at immersion depths of 2.5 to 5 in. (Fig. 11).

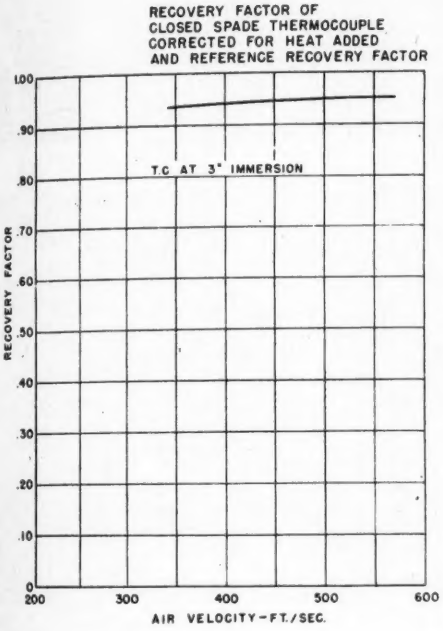


Fig. 9.

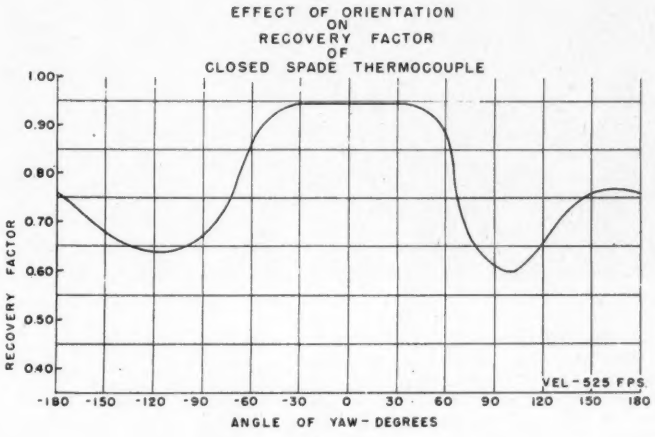


Fig. 10.

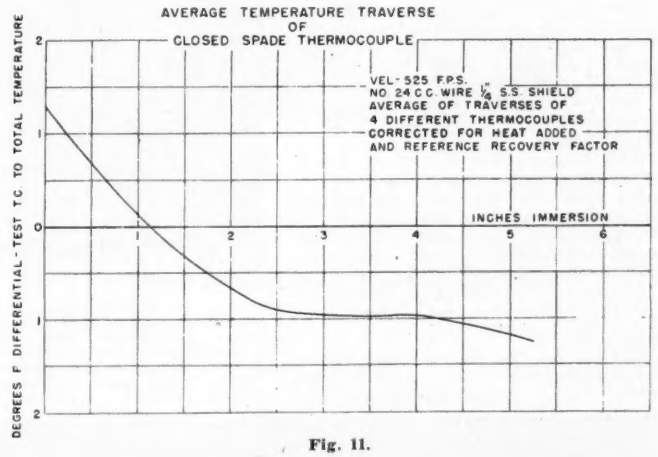


Fig. 11.

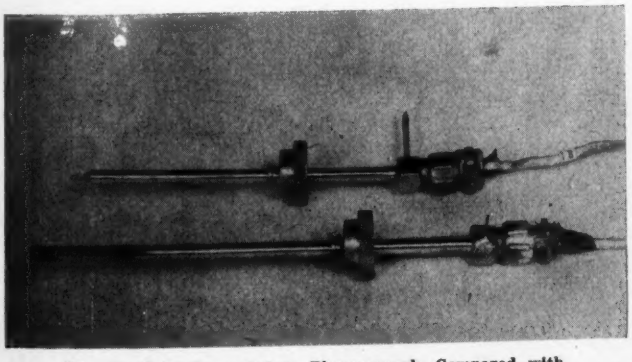


Fig. 12. Total Temperature Thermocouple Compared with Standard Thermocouple.

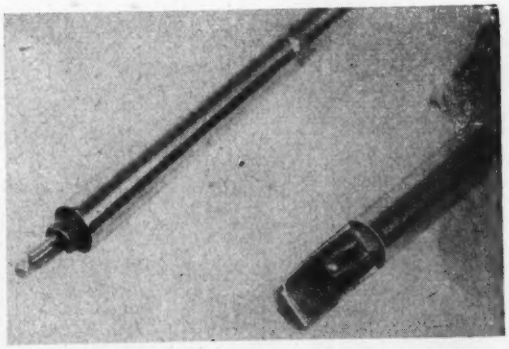


Fig. 13. Total Temperature Thermocouple Compared with Standard Thermocouple.

NEW YORK SECTION CONFERENCE

A view of the first technical Session.

Notes on January Conference*

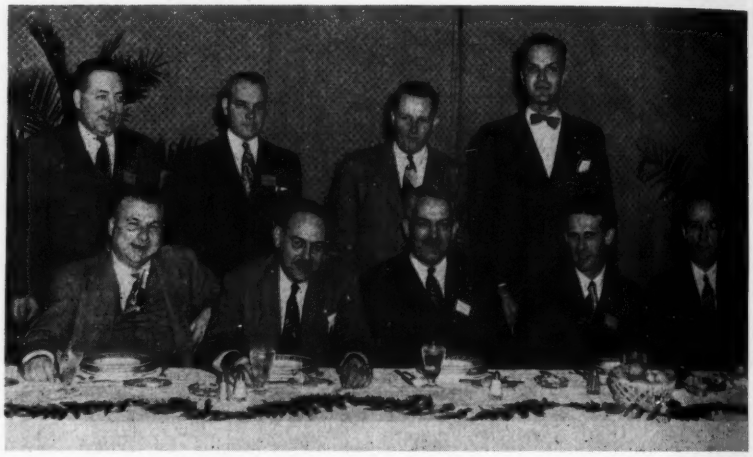
The untiring efforts of Mr. C. J. Zeller and his committee, which included Messrs. Ralph R. Batcher, Howard R. Kalbfleisch, L. Van Blerkom, Charles H. Yocum, S. G. Stemmer and J. W. Bennett, produced an outstanding conference program.

The Technical Program on Friday, January 26, was a well-rounded and completely satisfying series of discussions on process control. The speakers covered process control from the basic principles through rigid analysis of new concepts, up to the latest in application design.

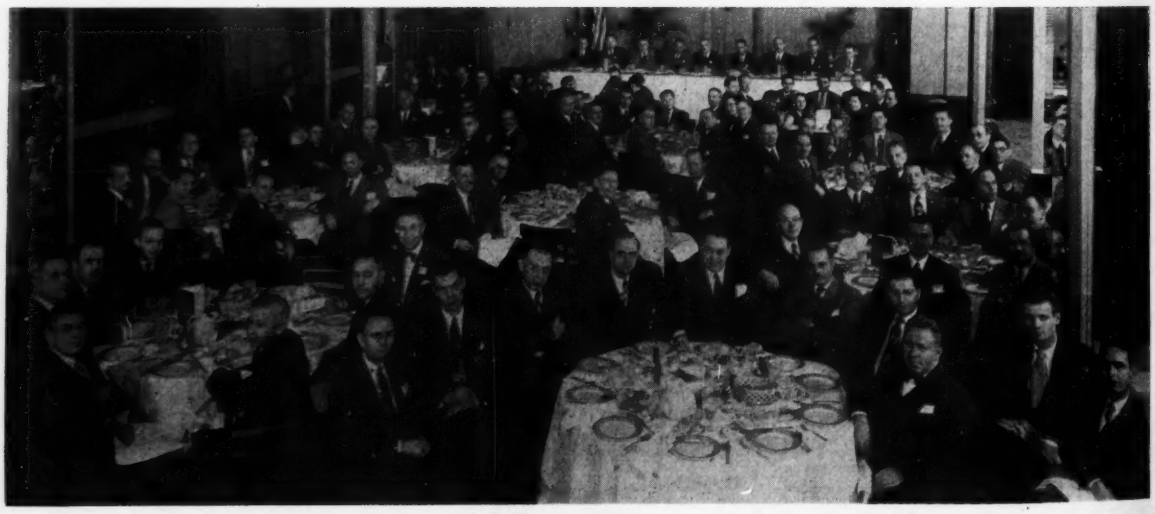
The Maintenance Forum on Saturday, January 27, was a veritable instrument man's dream. Lectures supplied by leading instrument companies ran the gamut of instrument maintenance techniques, from simple preventive maintenance through major overhaul.

Statistically speaking, the total registration of 221 rates this conference as one of our best attended.

* Reprinted from the February issue of the *New York Integrator*, New York Section Publication.



On the dias at the dinner meeting Friday, January 26 (left to right, standing) Ralph R. Batcher, program chairman of the conference; C. J. Zeller, general conference chairman; George R. Feeley, national treasurer ISA; Nelson Gildersleeve, national vice president ISA. (Left to right, seated) L. Van Blerkom, vice president New York Section; Richard Rimbach, executive secretary ISA; J. B. McMahon, national president ISA; C. E. Haggerty, president New York Section; Edward Scheidt, Special Agent in Charge, U. S. Department of Justice, Federal Bureau of Investigation, the guest speaker.



At the dinner meeting.

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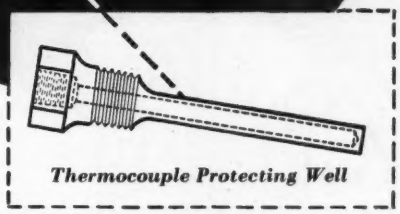

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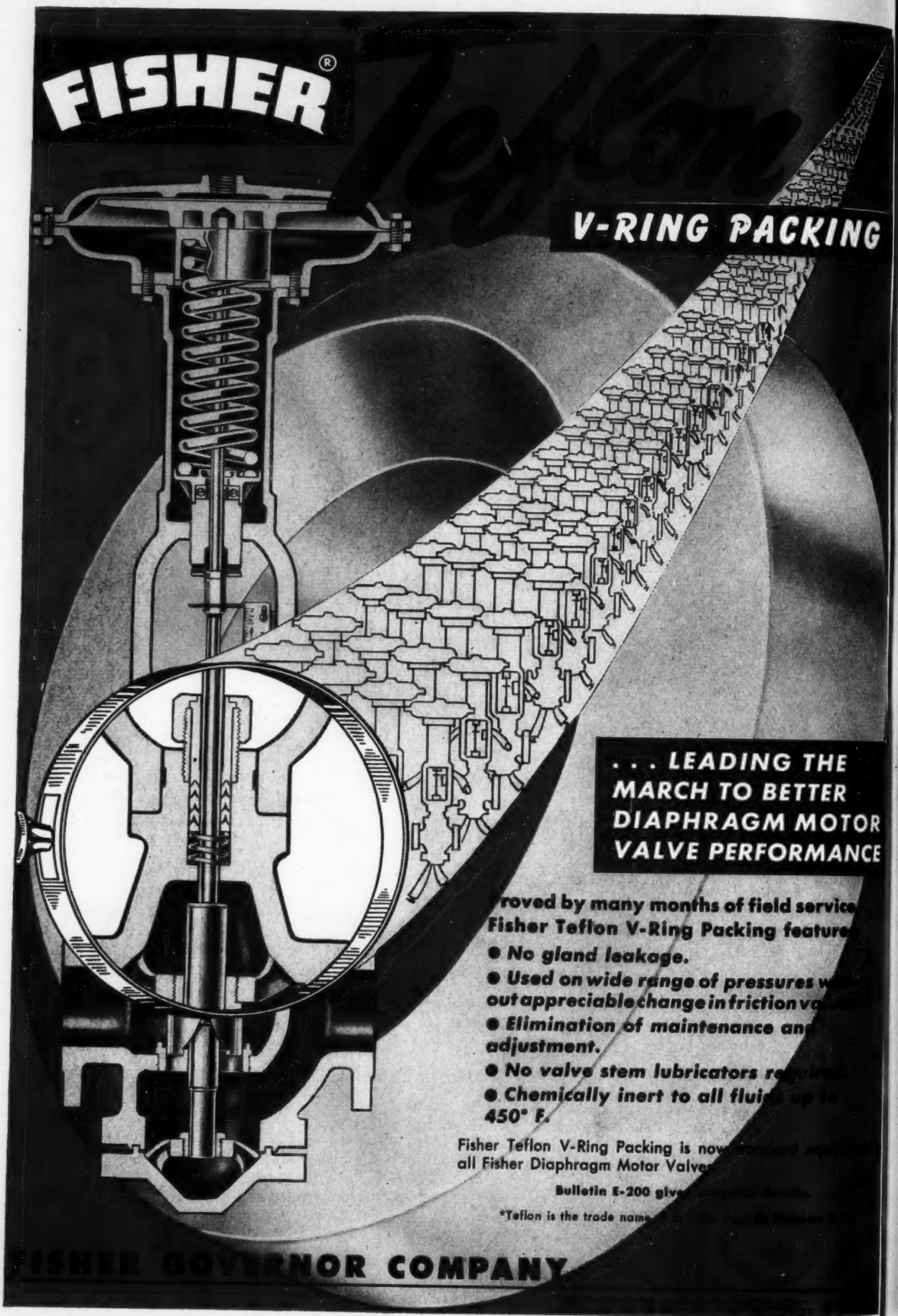
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Gas Pipeline Flow Calculations

By H. R. ROSS, California Railroad Commission

GAS pipelines are the heart of any gas company, whether it is purely a distributing agency, purely a transmitting agency, or a combination of the two. Natural gas is first carried from the original source (outlet of a gasoline absorption plant or a dry gas well) in gas-gathering or collecting lines. These gathering lines deliver their gas to transmission lines, which generally are fed from a number of gathering lines, and the transmission lines transport the gas to the vicinity in which the gas is to be distributed for consumption, at which point the gas is delivered to a network of pipes termed distribution lines. These distribution lines carry the gas to the service connections of ultimate customers, whence service lines conduct the gas to the meter, and from that point house piping or house lines complete the delivery of gas to the ultimate point of use.

To bring out the relation of metering to the carrying of gas from its source to the point of ultimate use, it can be said in general that the volumes are metered at the original source and at the junctions of each of the types of lines as previously classified, except for the junction of distribution and service lines. In addition, the volume of gas is usually measured immediately before and after undergoing compression, wherever that compression may take place. The measurement at all points prior to the ultimate, or consumer's, meter is usually performed by inferential meters of the orifice type due to the large volumes involved and the small pressure drop permissible, and also due to the prohibitive cost of positive displacement meters in such applications, but the ultimate meter is usually of the positive displacement type. Where the ultimate use involves large volumes, frequently orifice meters are used.

April Meeting: Thursday the 19th, Rio Hondo Country Club, Downey, Calif. Dinner at 6:30, Meeting at 8:00 p.m.
Feature: "Telemetering" by J. W. Peckham, The Bristol Company.

The theory and formulas to be presented apply universally to all gas pipeline flow, regardless of the particular type of line, as above classified by function; however, the calculations emphasized relate primarily to fairly high pressure and long distance lines, commonly called transmission lines.

By the use of the principle of conservation of energy, the following gen-

*Presented at a meeting of the Southern California Meter Association.

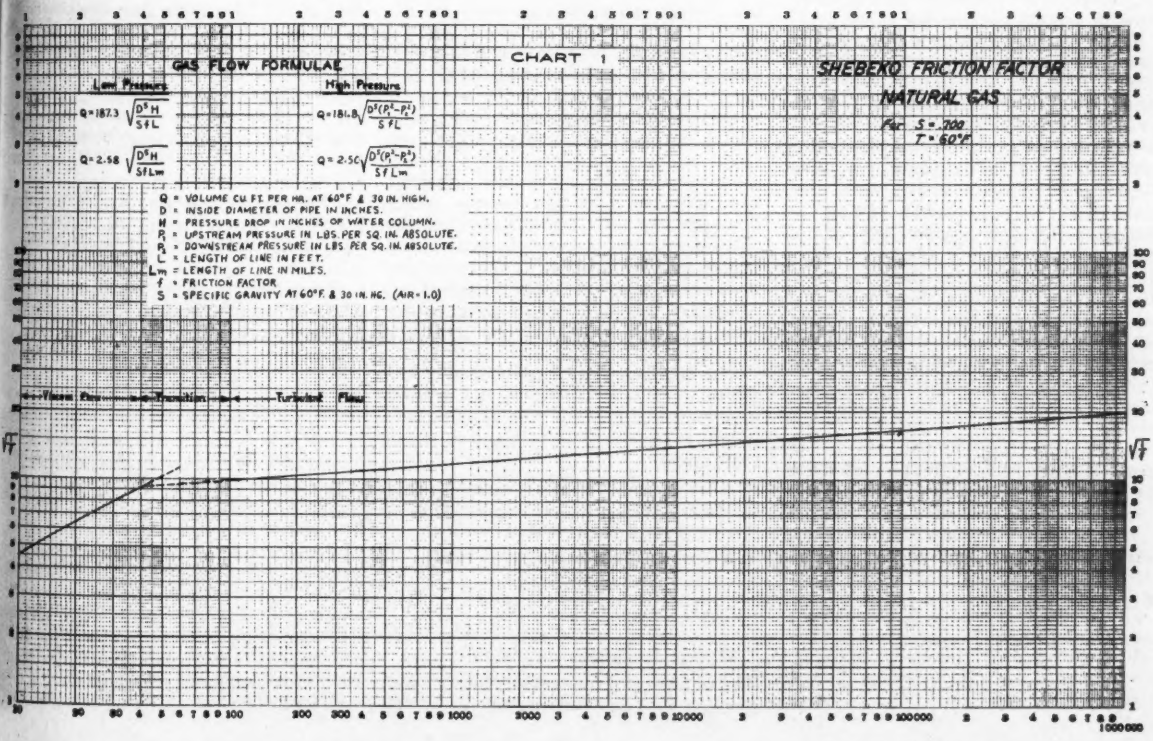


CHART 1
GAS FLOW FORMULAE
Low Pressure
High Pressure
Q = VOLUME CU FT PER HR. AT 60°F & 30 IN. HIGH.
D = INSIDE DIAMETER OF PIPE IN INCHES.
H = PRESSURE DROP IN INCHES OF WATER COLUMN.
P1 = UPSTREAM PRESSURE IN LBS. PER SQ. IN. ABSOLUTE.
P2 = DOWNSTREAM PRESSURE IN LBS. PER SQ. IN. ABSOLUTE.
L = LENGTH OF LINE IN FEET.
Lm = LENGTH OF LINE IN MILES.
f = FRICTION FACTOR
S = SPECIFIC GRAVITY AT 60°F & 30 IN. HG. (AIR = 1.0)
SHEBEKO FRICTION FACTOR
NATURAL GAS
For S = .700
T = 60°F
Turbulent Flow

eral formula for the flow of gases through pipelines has been developed:

$$Q = K \frac{T_o}{P_o} \sqrt{\frac{(P_1^2 - P_2^2) D^5}{GTLf}}$$

wherein Q = cubic feet per unit of time at base temperature and pressure
K = constant depending upon units used
T_o = temperature base, deg. F. abs.
P_o = pressure base, psi. abs.
P_1 = initial pressure, psi. abs.
P_2 = terminal pressure, psi. abs.
D = inside diameter of pipe, inches
G = specific gravity of gas with respect to air
T = flowing temperature, deg. F. abs.
L = length of pipeline, feet or miles
f = friction factor, no units (empirically determined)

The units indicated above are those generally used in this work, but any other units may be used equally well if the constant is correspondingly adjusted. The temperature and pressure bases as well as the flowing temperature may be included in the constant for a more specialized modification of the general formula.

$$Q = K_1 \sqrt{\frac{(P_1^2 - P_2^2) D^5}{GLf}}$$

There are many flow formulas, but they are all modifications of the above theoretically derived equations, the differences being in the friction factor. Such differences in friction factor between flow formulas may cause as much as 25 percent variation in calculated flow in certain pipe sizes.

Each of the earlier flow formulas, expressing friction factor as a relatively simple function (such as the Weymouth and Spitzglass formulas where the friction factor is expressed directly as a function of diameter only), applied quite well to the flow conditions under which the friction factors were evaluated, but generally could not be applied satisfactorily over a wide range of flow conditions. It was only when the friction factor came to be expressed in terms of line diameter, velocity, density and viscosity of the gas that results of most experimenters began to agree very closely. The expression involving these items, which is dimensionless, is commonly referred to as Reynolds' Criterion, or Reynolds' Number.

Reynolds' Number was arrived at from experiments on the flow of fluids, by observing the factors which appeared to determine whether flow would be streamlined or turbulent. The following expresses the relation of the various factors affecting the characteristics of flow:

$$\text{Reynolds' Number } R = \frac{dv}{\frac{u}{p}} = \frac{dvp}{u}$$

wherein d = inside diameter of pipe, feet
v = flowing velocity, ft., per sec.
p = flowing density, lbs. per cu. ft.
u = absolute viscosity, lbs. per sec. ft.

This Reynolds' Number subsequently was used as a means of expressing friction in gas pipeline flow formulas, and experimentation has substantiated that it is admirably suited to this purpose.

Many experimenters have proposed formulas expressing friction in terms of Reynolds' Number, many of them offering a number of formulas for different ranges of pipe size and type and condition of the inside pipe surface. The work of Kemler and Pigott along this line has been widely accepted as according with experience, and in graphical form can be presented as a "family" of curves. Determining the friction factor from such a set of formulas or curves is obviously more arduous than would be the case if one formula or curve could be used, and in order to simplify such determination Shebeko has proposed a single formula which lies approximately midway between the extremes of the curves of Kemler and Pigott and is considered representative of average pipe conditions in the West. Shebeko's formula yields satisfactory results except where extreme accuracy is required.

The following two adaptations of the Shebeko friction factor to the general flow formula are for the cases where length is expressed in feet and in miles, respectively:

$$Q = 181.6 \sqrt{\frac{(P_1^2 - P_2^2) D^5}{GLf}}$$

Where L = length in feet

$$Q = 2.50 \sqrt{\frac{(P_1^2 - P_2^2) D^5}{GLf}}$$

Where L = length in miles

The values of f in terms of Reynolds' Number (R) for respectively turbulent (R greater than 4000) and viscous (R less than 4000) flow are as follows:

$$f_{\text{turbulent}} = .0351 \left[\frac{1}{R}\right]$$

$$f_{\text{viscous}} = 16/R$$

Reynolds' Number for essentially all transmission line flow exceeds 4000 and for that reason the value of f used in the following discussion will be for turbulent flow only.

Since Reynolds' Number is made up of factors which are not generally used or thought of in practical gas work, it simplifies calculation of the value of f very materially to express R in terms of more commonly used factors. Mr. W. C. Mosteller has expressed R as a function of the ratio Q/D by the expedient of establishing as constant the specific gravity, temperature and viscosity, providing for subsequent correction of results to values at variance with those assumed as constant. Mosteller obtains R = 33.42 Q/D for the following assumptions:

Flowing temperature	T_f = 520 F. abs.
Specific gravity	G = 0.700
Absolute viscosity	u = 0.0000068 lbs./sec. ft.

Substituting this value of R in Shebeko's formula for friction factor for turbulent flow:

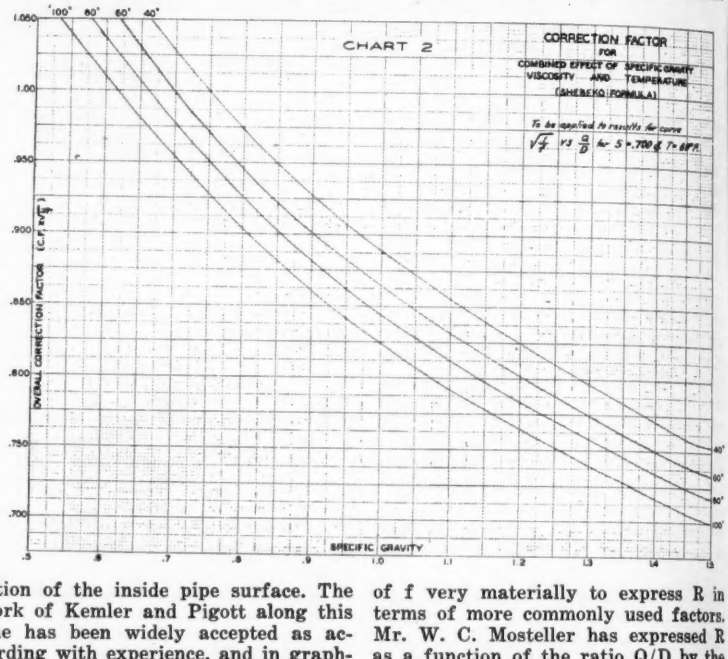
$$f = .0351 \left[\frac{D}{33.42\ Q}\right]^{.152}$$

or, for convenience in application to the flow formula:

$$\sqrt{1/f} = \frac{1}{\sqrt{.0351}} \left[\frac{33.42\ Q}{D}\right]^{.076}$$

The plot of this relationship is shown on Chart 1. Chart 2 presents curves for various ordinarily-encountered temperatures plotted against specific gravity and specific gravity-temperature-viscosity correction factor, permitting correction for actual values at variance with those assumed in Chart 1.

Calculating flow (Q) or diameter (D)



by the use of the resulting flow formula introduces what seems to be a paradox in that the answer must be known in order to arrive at the answer. However, the value of $\sqrt{1/f}$ varies so slightly relative to Q or D that two or three (at the most) successive approximations will give satisfactory results. There are methods of avoiding this solution by successive approximation, but they further complicate the determination and are recommended only where great numbers of calculations are made.

To obtain Q (or D), the procedure in the case of a uniform-diameter series pipe line is to guess at D (or Q), determine $\sqrt{1/f}$ from Chart 1; then substitute the first-approximated value of Q (or D) to make a second approximation of $\sqrt{1/f}$ and Q (or D). Three approximations (after the first guess) will be sufficient. Values of factors other than Q or D can be determined directly without successive approximation from the formula or curves. The correction from Chart 2 (if required) is then applied to the preliminary result as a coefficient of $\sqrt{1/f}$.

Very frequently it is necessary to calculate the flow in a series pipe line made up of different-sized pipe. If the problem were to find the total pressure drop in such a line, given all the necessary factors including initial pressure, the pressure drop could be calculated for each successive section of different-sized pipe, and the terminal pressure thus arrived at. Solving in this manner for pressure drop, although laborious, would permit direct solution of the formula for each successive section; however, if the problem were to find the flow in such a line, given the initial and terminal pressures and other necessary factors, the problem would become vastly more protracted as it would then be necessary to cut and try various Q's until one was determined which would give the desired terminal pressure. The magnitude of such a task can be appreciated particularly when it is realized that for each trial, a separate friction factor for each different-sized section would be required. For both of these types of problems, a very useful device is to convert all the lengths of different-sized pipe to the *equivalent length* of a single size, from which point the problem can be solved as a simple continuous single-sized line.

Any line is the equivalent of another when the same difference of the squares of absolute pressure ($P_1^2-P_2^2$) impels the same flow (Q) through each of them. Thus it can be seen that a greater length of a larger diameter line would be the equivalent in carrying capacity of a shorter smaller-diameter line. Using the preceding definition of equivalence in the general flow formula and identifying the actual line by the subscript "a" and the equivalent line by the subscript "e", by collecting to one side all the factors which, by the definition given, will be the same for both lines, it follows that the values of the other side of each of these equations must be equal to each other. Using this equality the following equivalence formulas have been derived for complex series lines:

$$L_e = [De/D_a]^{4.848} L_a, \text{ or}$$

$$D_e = [L_e/L_a]^{0.2063} D_a$$

It is also possible to convert two or more parallel lines to an equivalent length of a single line. With parallel lines, the initial and terminal pressures are common to each of the lines. Using any value for ($P_1^2-P_2^2$), calculate the flow through each of the branches, add the resulting flows together, then solve for length (or diameter) of the equivalent line, that is, one which will carry the combined flow with the same value of ($P_1^2-P_2^2$). This method of calculation can also be applied to a complex series line, that is, for each different size of line in the series, an equivalent length can be calculated for an assumed equivalent diameter by determining the equivalent dimensions (length and diameter) which will yield the same flow for the same value of ($P_1^2-P_2^2$), identical results being obtained regardless of the magnitude of the value of ($P_1^2-P_2^2$) selected.

The theoretical flow formulas discussed thus far have been based upon the assumption that flowing gases conform to Boyle's Law, which is not the case with actual gases. This deviation from Boyle's Law introduces a successively more appreciable error as higher pressures are reached. In orifice meter work it is necessary to know only the downstream pressure, temperature and gravity to obtain the proper factor to apply, since the pressure is essentially constant, but in the case of pipe line flow theoretically a different factor would have to be applied for each of an infinite number of different pressures. It has been shown by Biddison that the effective deviation factor for such a line as a whole is the factor corresponding to the mean effective pressure P_m (*not* the mean of initial and terminal pressures) on the flowing line.

P_m is obtained on the theory that, in a constant-sized line, the value of ($P_1^2-P_2^2$) per unit of length is the same from one end of the line to the other. Knowing that the flow at any cross-section along the line is the same as at any other cross-section, an expression for an intermediate pressure P at an intermediate point L can be obtained in terms of P_1, P_2, L and L_2 ($L_1 = 0$) as follows:

$$\frac{P_1^2-P^2}{L} = \frac{P_1^2-P_2^2}{L_2}; \quad P_1^2-P^2 = (P_1^2-P_2^2)\ L/L_2 \text{ or}$$

$$P^2 = P_1^2-(P_1^2-P_2^2)\ L/L_2, \text{ or}$$

$$P = \sqrt{P_1^2-(P_1^2-P_2^2)\ L/L_2}$$

Integrating the area under the curve (of falling pressures) represented by this equation, and dividing this area by the over-all length of line L_2, we have

$$P_m = \tfrac{2}{3}\frac{P_1^3-P_2^3}{P_1^2-P_2^2} = \tfrac{2}{3}\left[P_1+\frac{P_2^2}{P_1+P_2}\right]$$

which is the mean effective pressure on the line.

The "deviation" or correction for deviation applicable to volume is expressed symbolically as "Y." In C.N.G.A. Bulletin TS-402 the deviation factor (F_{PV}) is in reality the square root of "Y," or $\sqrt{Y}$. Applying the deviation "Y" to the basic orifice meter flow formula

$Q = K\sqrt{hP/GT}$, we arrive at

$Q = YK\sqrt{hP/YGT}$, or

$Q = \sqrt{Y}\ K\sqrt{hP/GT}$, or

$Q = F_{PV}\ K\ \sqrt{hP/GT}$ from which it is seen that deviation affects not only the volume or flow but also the specific gravity of the flowing gas; hence the application of $\sqrt{Y}$ or F_{PV} to the uncorrected results.

Similarly in the pipe line flow basic formula

$$Q = K\sqrt{\frac{(P_1^2-P_2^2)D^5}{GLf}}$$

the deviation affects both the volume and the specific gravity of the flowing gas, so the same over-all correction as used for orifice meter flow can be used for pipe line flow as follows:

$$Q = \sqrt{Y}\ K\sqrt{\frac{(P_1^2-P_2^2)D^5}{GLf}}, \text{ or}$$

$$Q = F_{PV}\ K\sqrt{\frac{(P_1^2-P_2^2)D^5}{GLf}}$$

As stated above, the deviation factor (F_{PV}) to be applied to uncorrected flow formula results is that corresponding to the mean effective pressure (P_m) on the pipe line.

The foregoing pipeline flow calculations (except for the correction for deviation) can be facilitated and simplified by the use of Shebeko's Polyflo Gas Flow Computer which yields results approximating slide rule accuracy, such accuracy being adequate for most purposes. This computer is widely used by the gas industry in the West. The details of its operation are felt to be beyond the scope of this paper, particularly since the manual of instructions accompanying the computer is sufficiently explicit and further due to the fact that unless one has a computer in his hands at the time, such explanation is largely incomprehensible. It is desired to bring out, however, that this computer provides a short-cut in low pressure distribution problems in that determinations can be made directly in terms of inches of water differential in pressure, which is the usual method of pressure measurement in this type of work, without conversion to pressures in pounds per square inch. This shortcut method gives exactly the same results as the previously presented universally applicable formula only at a terminal pressure of 14.7 psi. absolute and with one inch of water column pressure drop, but does not introduce serious error if used within the intended distribution range. For values in excess of those stated, the shortcut method gives successively more conservative results.

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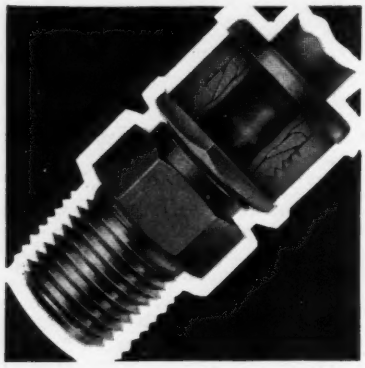

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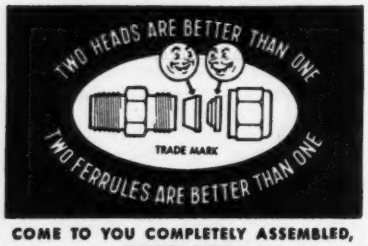

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Comments by J. B. Reddick, Southern California Gas Company.

The writer would like to take this opportunity of emphasizing the inference of the author that formulae of the Weymouth and Spitzglass type are now as obsolete as the Pole and Molesworth formulae became, when the former were generally adopted by the Gas Industry.

The friction factor "F" is the trouble maker as may be inferred from the author's paper. Its value is always a matter of argument and speculation and it is around its evaluation that study and experiments are concentrated. If a correct value of "F" could always be found, then the solution of pipe line flow would be practically exact.

As stated by the author, the friction factor expressed in terms of the Reynolds number is the best method of correlation up to this time. Yet its value to the Engineer depends on the employment and substitution of proper or reasonably close values in the formula. The more nearly the values represent the conditions, the more accurate the results.

The writer prefers to write the gas expression for Reynolds number as follows: $R = 0.4822\ QG/DZ$ wherein Z is the viscosity in centipoises.

Using Mr. Mostellers special case of $G = 0.70$ and transforming his absolute viscosity of 0.0000068 to centipoises, the equation above yields $R = 33.35\ Q/D$. In both expressions "Q" is the volume Cu.Ft.Hr.

Up to the present time the effect of pressure on viscosity as related to pipeline flow has been disregarded and the viscosity at atmospheric pressure used for all pressures.

Sage and Lacey in a paper entitled "Effect of Pressure upon Viscosity of Air, Methane and Two Natural Gases" (Technical Publication No. 845 of the Institute of Mining and Metallurgical Engineers Inc., 1937) show that viscosity does increase with pressure. With the trend towards higher pressures this may have an important effect. It has been calculated that at a mean pressure of 500 psi. this characteristic of viscosity may introduce of itself, an error of about −4.5 percent in the final results.

More knowledge on this particular subject should be of primary interest.

For pipelines of equal length, pressures and diameter, but of varying internal condition, there must be varying capacities. Hence, each pipeline has its own individual friction factor due to this variety of internal wall conditions.

This roughness factor is practically impossible of evaluation except for reasonable approximations. Considerable research and thought is now being given this phase. It was not intended to lengthen these comments into a discussion of this matter, however the reader is referred to the following literature: "Evaluation of Boundary Roughness" by Hunter Rouse (Proceedings of Second Hydraulic Conference, University of Iowa Bulletin #27, 1943); "Friction Factors for Pipelines" by Lewis F. Moody (Transactions of A.S.M.E., Hydraulic Division, 1944).

For nearly 200 years investigators have been struggling with this roughness factor, making progress slowly. It may never be evaluated entirely but the nearer the truth is approached the narrower the limits of error will become in the final results.

Comments by J. T. Cortelyou, Southern California Gas Company.

As Mr. Ross points out the most generally available source of this data is the California Natural Gasoline Association Bulletin TS 354. Unfortunately, this Bulletin contains data for pressures only up to 500 psi., and modern gas transmission practice trends towards pipeline pressures up to 1000 psi. or greater. Extrapolations with empirical equations in this Bulletin beyond 500 psi. would be most inaccurate.

The best source of high pressure data for this purpose is the superexpansibility data based on the theory of corresponding states and psuedo critical pressures and temperatures which has recently been developed by many investigators and has been summarized by the Natural Gasoline Association of America in their Tentative Standard Method for Calculation of High Pressure Gas Measurement. This publication presents an adequate presentation of the "psuedo critical" method as well as actual data for the pipeline engineer.

The psuedo critical pressure and temperature are best determined from an analysis of the composition of the flowing gas. This information is usually not readily available. The Natural Gasoline Association of America has therefore developed a correlation of psuedo-critical pressures and temperatures with specific gravity for certain types of Mid-Continent gases.

It is the writer's belief that this correlation holds within the limits of practical pipeline accuracy for California gases as well as Mid-Continent gases. Therefore the Natural Gasoline Association of America's data is sufficient for providing superexpansibility data for California pipeline engineers when pressure, temperature, and specific gravity are known.

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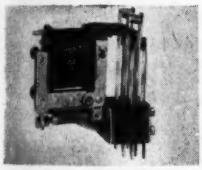
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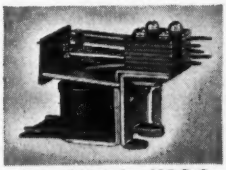
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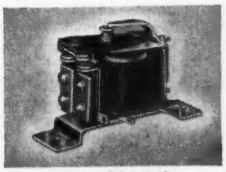
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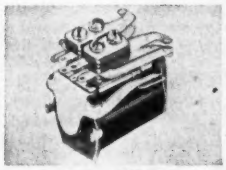
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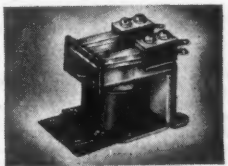
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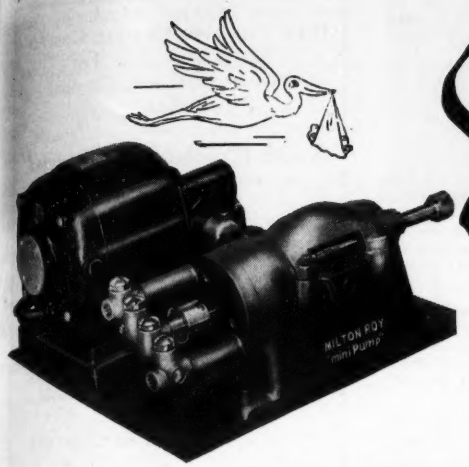

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T-225 INTERNAL COMPARATOR GAGE. 8-page Bulletin 40 illustrates and describes maker's "Comtorplug" production and inspection gage; discusses application, operation and accuracy, capacities and types; includes diagrams on internal construction.—The Comtor Co., Waltham, Mass.

T-226 RHEOSTATS. 2-page house organ, January 1951 issue of "The Ohmite News," features articles on application of rheostats to lamp dimming and rheostat design.—Ohmite Manufacturing Co., 4835-41 Flournoy St., Chicago 44, Ill.

T-227 OIL-TANK TEMPERATURE RECORDERS. 4-page house organ, Vol. 10, No. 2 issue of "Wheelco Comments," features articles on applications of maker's resistance thermometers to petroleum and ceramics indutries.—Wheelco Instruments Co., 847 W. Harrison St., Chicago 7, Ill.

T-228 ENGRAVER. 6-page Bulletin L45-1 illustrates and describes maker's "Panto" utility engraver, electrical marker and acid etcher; includes specifications.—H. P. Preis Engraving Machine Co., 155 Summit St., Newark 4, N. J.

T-229 PAINT TESTING INSTRUMENTS. 32-page catalog describes and illustrates 75 items available for testing viscosity, film thickness, drying time, hardness and adhesion, appearance, color, gloss, etc.; includes price list.—Gardner Laboratories Inc., Bethesda, Md.

T-230 PRESSURE EQUALIZER. 2-page pamphlet illustrates and describes maker's pressure equalizer and discusses it's installation and application to brewery industry.—Micromat Co., 53-22 Roosevelt Ave., Woodside, New York, N. Y.

T-231 RADIO TRANSMISSION. 4-page house organ, Vol. 4, No. 1 issue of "Amphenol Engineering News," features article on a new means of high-frequency radio transmission; includes article on Welch "Densichron" for measuring density and light transmission.—American Phenolic Corp., 1830 S. 54th Ave., Chicago 50, Ill.

T-232 POLARIZATION FOR REFLECTION CONTROL. 4-page house organ, No. 1, Jan. 1951 issue of "Polaroid Reporter," features article "Circular Polarization for Reflection-Control" and items on new polarizer and band-pass filter for the infrared.—Polaroid Corp., Cambridge 39, Mass.

T-233 SPECTROMETRY. 8-page house organ, Vol. 2, No. 2 issue of "Instrument News for Science and Industry," features article on oscillographic methods for infrared spectrometry; includes articles on theory and design of high-speed thermocouples, photometry, product control and use of electrophoresis in cancer research. —Perkin Elmer Corp., Norwalk, Conn.

T-234—POWER AMPLIFIER. 8-page house organ, Vol. XXV, No. 8 issue of "The General Radio Experimenter," features article on aperiodic power amplifier; includes complete data on applications, circuit, output system, voltmeter, specifications, etc.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

T-235 RECORDING EQUIPMENT. 4-page Project Digest PD-15 illustrates and describes maker's recording and playback equipment used in the analysis and storing of scientific test data.—Cook Research Laboratories, 1457 Diversey Parkway, Chicago 14, Ill.

T-236 CAPACITATORS. 2-page Bulletin 6.531 illustrates and describes maker's subminiature tantalum capacitors; lists nine standard capacitors ranging from 30 mfd at 6 volts d.c. to 3.5 mfd at 75 volts d.c..—Capacitor Div., Fansteel Metallurgical Corp., North Chicago, Ill.

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T-239 INSULATION RESISTANCE TESTING. 2-page bulletin illustrates and describes maker's "Vibrotest" for push-button insulation resistance testing; includes list of models, ranges and advantages.—Associated Research, Inc., 3758 W. Belmont Ave., Chicago 18, Ill.

T-240 STATIONARY TACHOMETER. 2-page Bulletin 794 illustrates and describes maker's "Model J-6" stationary tachometer designed for permanent mountings on machines or panels.—Herman H. Sticht Co., Inc., 27 Park Place, New York 7, N. Y.

T-241 POWER SUPPLY. 4-page bulletin illustrates and describes maker's "Model 301" portable power supply for controlled electrode potential electrolysis; includes specifications, applications and description.—Sanford Development Laboratories, 3001 Upshur St., Mount Rainer, Md.

T-242 PROCESS CONTROL EQUIPMENT. 4-page Bulletin 0550 illustrates and describes maker's proportioning, blending and process control equipment.—Richardson Scale Co., Clifton, N. J.

T-243 TEMPERATURE-CONTROLLED VALVE. 4-page catalog illustrates and describes maker's "Model Y" temperature-controlled valve; discusses operation, features, temperature range and applications.—Burling Instrument Co., 5 Vose Ave., South Orange, N. J.

T-244 REGULATOR. 4-page Bulletin 1245 illustrates and describes maker's "Type 2-SO" oil-powered diaphragm-actuated pilot-type regulator; discusses construction features, operating characteristics and adjustments; includes engineering diagram.—Hagan Corp., Hagan Bldg., Pittsburgh 30, Penna.

T-245 SAFETY VALVE. 2-page bulletin illustrates and describes maker's "Sibal" safety valve for beer tanks (closes automatically as soon as excess pressure is blown off).—Micromat Co., 53-22 Roosevelt Ave., Woodside, New York, N. Y.

T-246 DRYERS. 4-page Bulletin 16.0.080 illustrates and describes maker's "Hydryers" for drying gases, air, or liquids for industrial processing and laboratory applications; discusses design and operation.—J. F. Pritchard & Co., 908 Grand Ave., Kansas City 6, Mo.

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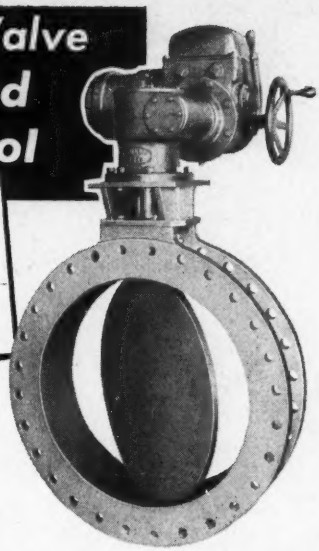

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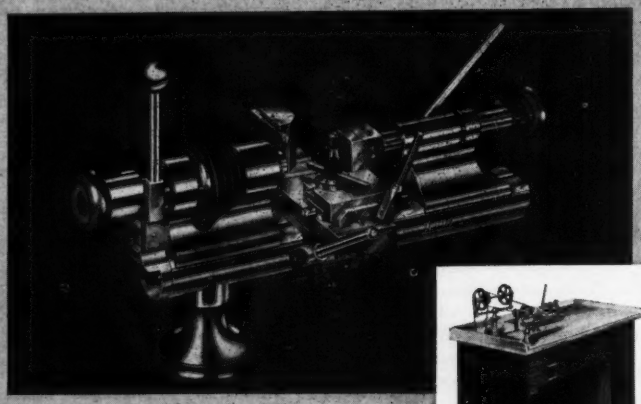

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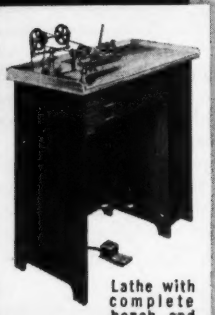

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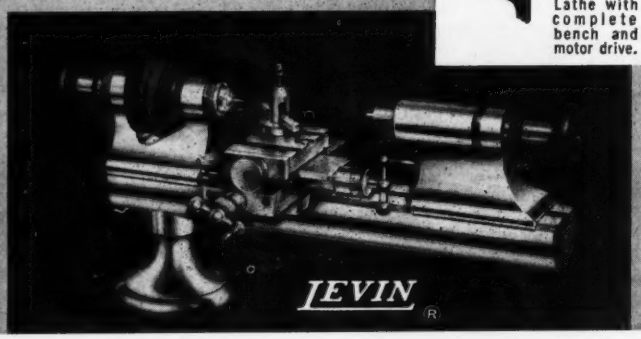

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T-250 AUTOMATIC COMBUSTION CONTROL. 12-page Bulletin DR-40 illustrates and describes typical installations of maker's automatic control; discusses function and need of control; includes diagrams on various types of installations.—Hagan Corp., Hagan Bldg., Pittsburgh 30, Penna.

T-251 METER SHUNTS AND MULTIPLIER DESIGN. 16-page house organ, Vol. 16, No. 1 issue of the "C-D Capacitor," features article on "Practical Design of Meter Shunts and Multipliers"; includes radio trading post "Swap" section.—Cornell-Dubilier Electric Corp., Hamilton Blvd., South Plainfield, N. J.

T-252 ENGRAVER. 2-page bulletin illustrates and describes maker's "Model 2D-4 Panto-engraver"; includes specifications and lists standard equipment.—H. P. Preis Engraving Machine Co., 651 State Highway 29, Hillside 5, N. J.

T-253 LABORATORY MIXER. 2-page bulletin illustrates and describes maker's laboratory mixer designed especially for breweries; 2, 4, or 6-beaker size listed in specification data.—Micromat Co., 53-22 Roosevelt Ave., Woodside, New York, N. Y.

T-254 RADIO-ELECTRONICS CATALOG. 132-page catalog of radio, television and electronic components is designed especially for industrial purchasing agents, research labs, schools, etc.—Sun Radio & Electronics Co., Inc., 122-124 Duane St., New York, N. Y.

T-255 ENGINE TESTING. 6-page Bulletin 9345 illustrates and describes maker's "Thru-Torq" for use in engine testing; discusses principle of operation, features, design etc.—Hagan Corp., Hagan Bldg., Pittsburgh 30, Penna.

T-256 SPECTROGRAPHIC ANALYSIS. 4-page Bulletin XXXV illustrates and describes maker's spectrographic source unit; includes specifications on control, a-c. spark, a-c. arc, d-c. arc, size and weight.—Baird Associates, Inc., 33 University Rd., Cambridge 38, Mass.

T-257 RELAY. 2-page Bulletin 401 illustrates and describes maker's a-c. voltage sensitive relay-power type; includes applications, descriptions, principles of operations and engineering diagrams.—Ward Leonard Electric Co., Mount Vernon, N. Y.

T-258 INSULATED PANELS. 2-page Bulletin WR-251 illustrates and describes maker's prefabricated insulated panels for construction of hot or cold walk-in test rooms.—Bowser Technical Refrigeration Div., Bowser Inc., Terryville, Conn.

T-259 TRANSFORMERS. 16-page Bulletin P550 illustrates and describes maker's "Powerstat" variable transformers; includes engineering diagrams and ratings.—Superior Electric Co., Bristol, Conn.

T-260 RATIO TOTALIZER. 8-page Bulletin 5450 illustrates and describes maker's ratio totalizer for application to control systems where there is need for combining control signals; discusses principle of operation, application, construction, accessories.—Hagan Corp., Pittsburgh 30, Penna.

T-261 WATER-LEVEL CONTROLLERS. 4-page Bulletin 1100 illustrates and describes maker's "Autocon Tanktrols" with twin bellow design for automatic maintenance of water levels in elevated tanks.—Automatic Control Co., St. Paul 4, Minn.

T-262 SPECTROGRAPH. 12-page Bulletin XXXII illustrates and describes maker's spectrographs for spectrochemical analysis, discusses grating spectrographs, performance and specifications as well as other pertinent data.—Baird Associates, Inc., 33 University Road, Cambridge 38, Mass.

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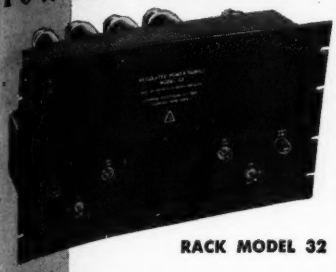

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T-265 ANEMOMETER. 2-page Catalog 102 illustrates and describes maker's "Air-meter" anemometer; discusses principle of operation, characteristics, accessories and includes price list.—Hastings Instrument Co., Inc., P. O. Box 1275, Hampton, Va.

T-266 THERMOCOUPLES. 24-page Catalog 12 illustrates and describes maker's thermocouple lead wires, thermocouple heads, thermocouples, insulators, wires, and tubes; includes data tables on various metallic content thermocouples and wire resistances.—Industrial Pyrometer & Supply Co., Alton, Ill.

T-267 INDUSTRIAL CONTROLS. 60-page Catalog 8304 illustrates and describes maker's industrial controls for temperature, pressure, flow, liquid level and humidity; discusses electric, pneumatic and combined electric-pneumatic automatic control systems; section on accessories included.—Industrial Div., Minneapolis Regulator Co., Philadelphia 44, Penna.

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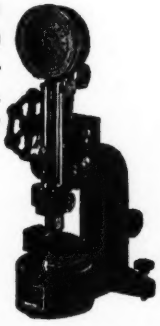

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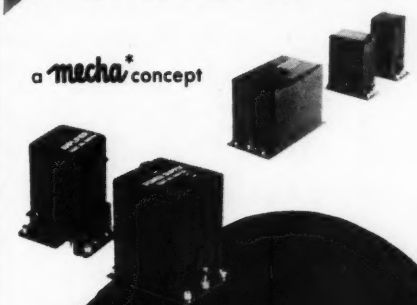

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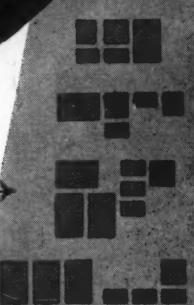

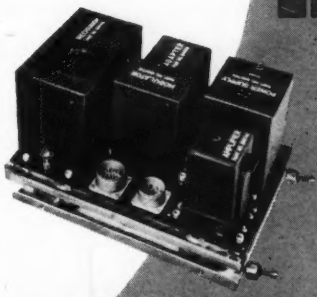

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